HISTORY OF HYDROCARBON RELEASES IN THE VILLAGE OF HARTFORD, ILLINOIS

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EXECUTIVE SUMMARY

Engineering-Science, Inc. (ES) is pleased to present this study of the history and nature of hydrocarbon releases in the Village of Hartford, Illinois, to Shell Oil Company's (Shell) Wood River Manufacturing Complex (WRMC). The purposes of this study are: (1) to provide a historical chronology of the subsurface hydrocarbon problem in the Village of Hartford, Illinois, particularly, the occurrence of fires and complaints of gas odors in the Village of Hartford; and, (2) to assess what role, if any, the December 16, 1989, Shell unleaded gasoline release north of Rand Avenue may play with respect to that problem. Review of the problem history of Hartford, as well as a physical and chemical differentiation of hydrocarbon plumes resulting from separate historical release events, clearly indicates that the subsurface hydrocarbon problem in Hartford has existed for the past 26 years. Data presented as a possible source of the subsurface hydrocarbon problem in the Village of Hartford eliminate the 1989 Shell pipeline release as a cause of the fire and odor complaints cited above.

Hydrocarbon-related odors and fires in Hartford homes have been well documented since the first complaints occurred in 1966, demonstrating that the problem existed prior to the Shell 1989 pipeline release. Village police records document 15 known leaks and releases prior to 1989.

An investigation by the Illinois Environmental Protection Agency (IEPA) was prompted by a series of five house fires that occurred during March 1978 in Hartford. As a result of that investigation, Clark Oil Company (Clark) prepared a voluntary remediation plan to recover what was then estimated to be from 1,000,000 to 9,000,000 gallons of product in the subsurface beneath the Village of Hartford.

After the fires that occurred in March and May of 1990, another inquiry by the IEPA resulted in a report issued in November 1990 (Appendix A) in which Clark was found to be responsible for the hydrocarbon contamination beneath Hartford. In the November 1990 report, the IEPA estimated that 900,000 to 3,800,000 gallons of product remain in the ground, and the IEPA demanded that Clark prepare a more aggressive remedial action plan.

SITE BACKGROUND

LOCATION

The Village of Hartford is located on the east bank of the Mississippi River, upstream from St. Louis, Missouri (Figure 1). The geographical region around Hartford and other nearby towns is collectively known as the American Bottoms, which encompasses an area of 175 square miles. The American Bottoms is a shallow valley 30 miles long and, at its widest point, 11 miles wide. The Mississippi and Missouri Rivers merge approximately one mile south of Hartford, and the enlarged Mississippi River flows south in an alluvial meander belt bordered on both sides by limestone bluffs.

The Mississippi River is lined by industrial barge-loading facilities owned by Shell, Clark, and the American Oil Company (Amoco). The Village of Hartford lies 1,500 feet east of the Mississippi River. The Shell Tannery Property and the Clark refinery are located directly east of the Village of Hartford. The Amoco facility lies north-northeast of Hartford across Rand Avenue. The Shell manufacturing complex is located east of the Clark refinery. Figure 1 shows the respective property boundaries of these facilities and their geographical relationship to Hartford. Figure 2 is a map of the northern portion of Hartford.

UNDERGROUND PIPELINES

The hydrocarbons in the subsurface beneath Hartford appear to have been caused by leaking underground product lines. Several product lines lie in proximity to Hartford, and have been identified as sources of hydrocarbon releases. Each of the three facilities (Amoco, Clark, and Shell) have underground product lines that transport hydrocarbons to barge-loading facilities located to the west along the Mississippi River. These product lines travel through or around Hartford. The locations of these product lines are shown in Figure 3. Amoco underground lines were not plotted on this map, since they are located approximately one-half of a mile north of Hartford. These lines are identified as:

- One 3-inch product line and three 8-inch product lines, all of which are owned by Clark. These product lines leave the Clark refinery and trend in a westerly direction toward Hartford. These lines continue through Hartford running parallel to Elm Street, continuing westward. These lines cross Illinois Route 3 and terminate at the Clark loading facility on the river.
- One 10-inch Clark Oil product line leaves the refinery in a westerly direction, but before reaching Olive Street, turns north and runs parallel to Olive Street.

This line crosses Rand Avenue and continues north to the Hartford/Wood River Terminal (formerly the Piasa Terminal).

- One 10-inch product line owned by Sinclair Oil (Sinclair) and operated by the Atlantic-Richfield Company (ARCO) exits the Clark refinery and parallels the 10-inch Clark line running north on Olive Street. This line also crosses Rand Avenue and terminates at the ARCO pump station north of the Hartford/Wood River Terminal.
- Ten Shell Oil product lines, as well as sewer and water supply lines, run from the Shell facility to the barge-loading facility located west of Hartford. The water and sewer lines parallel Rand Avenue in Hartford. The product lines angle north of Hartford east of Olive Street, then run parallel to Rand Avenue near Illinois State Highway 3. The ten product lines include one 10-inch, one 12-inch, and two 6-inch aboveground lines, and six 8-inch buried product lines.

RELEASE/LEAK HISTORY

The IEPA and Hartford Police records document 15 known hydrocarbon releases in the immediate Hartford vicinity (Figure 4). These records vary from a brief mention in reports to detailed documentation in activity logs. The first known hydrocarbon release was in 1973, from a Shell river line north of Rand Avenue near Hartford. The product leaked was benzene and this release is documented by records located in Appendix B. The next documented hydrocarbon release was a gasoline release on February 22, 1977, and was reportedly from the 10-inch line owned by Sinclair and operated by ARCO. The amount and location of the release was not identified in the report titled *1978 Investigation into Methane/Hydrocarbon Odors in the Village of Hartford* conducted by the Hartford Police Department (Appendix C). This same report states that a leak at the intersection of Olive Street and Rand Avenue was repaired April 20, 1977, but does not reference the source or type of product released. Shell has no record of a product release from any pipelines during this period. The report also notes that a fuel oil or gasoline release occurred from a Clark line on Rand Avenue, between Delmar Avenue and Olive Street, during March 1978. Shell has no record of a product release from any pipelines during March 1978.

On April 27, 1978, a leak from one of Clark's 8-inch river lines was discovered in Hartford on Elm Street, near Delmar Avenue. This release is documented and photographed in the 1978 Hartford Police Investigation (Appendix C). On April 28, 1978, the pipeline was repaired and tested. The pressure test conducted after pipeline repairs were completed indicated that a leak was still present. On May 1, 1978, Clark was reported to have uncovered and tested sections of their pipelines that run along North Olive Street for leaks. There are no reports of any other pipeline leaks.

Another leak along Elm Street from Clark product lines occurred on October 17, 1978. This leak is documented in Attachment 2 of the 1990 IEPA report (Appendix A). This report also documents three ARCO releases:

- January 8, 1981 - 5 barrels of gasoline
- July 12, 1981 - 24 barrels of gasoline, and
- June 7, 1982 - 9 barrels of fuel oil

These releases occurred at unreferenced locations along the Sinclair-owned/ARCO-operated product line near Olive Street.

Records from the Hartford Police indicate that diesel fuel was released from product lines owned by Clark, near East Forest Street at Olive Street, on November 10, 1982. On December 31, 1982, it was reported that an undetermined volume of oil was released from a Clark-owned pipeline in the vicinity of the November release (Figure 4).

On April 16, 1983, a Clark-owned hydrocarbon-recovery tank, located at the corner of Date and Olive Streets (Figure 4), was reported as being overfilled with product. No mention was made as to the volume of product lost.

A light-cycle oil release was reported from an abandoned 3-inch Clark-owned river line on November 20, 1984. Product seeped to the surface at East and West Elm Streets when it was inadvertently pumped into the abandoned pipeline. The Hartford Fire Department washed the surface seepage into the storm water sewer. The sewer emptied into the Mississippi River, where an oil slick formed. The United States Coast Guard was called upon to clean up the slick. The volume of the release is unknown. The release was documented by the IEPA. This documentation can be found in Attachment 2 of Appendix A.

Another release from Clark property occurred on September 26, 1987, when the skimmer pump of the Clark Recovery Well No. 2, installed at the corner of Olive and Cherry Streets, failed to shut off, thereby causing the holding tank to overfill. The volume of this release is also unknown.

The most recent release in the Hartford area occurred on December 16, 1989, when a buried Shell pipeline, northeast of the intersection of Rand Avenue and Olive Street, ruptured (Figure 4). An estimated 294,000 gallons of unleaded gasoline were released from this ruptured line. IEPA records of the release appear in Attachment 2 of Appendix A.

Table 1 lists the releases cited above, and the documented locations of the hydrocarbon releases in the immediate vicinity of Hartford, Illinois, are shown on Figure 4.

In addition to these documented releases, there is evidence that some product lines had developed slow, continuous leaks. In a report issued by the IEPA in November 1990, Mr. Mark Shrimpe, Vice President of the Hartford/Wood River Terminal, reported that the 10-inch Clark product line along Olive Street may have been leaking when it was in service. The pipeline has been abandoned for an unknown number of years, although the Hartford/Wood River Terminal formerly received product from this line. Inventory shortages averaged 360 barrels a week. This shortage was due to either a leak in the pipeline, malfunctioning gauges at the terminal or at the Clark refinery, or both. Mr. Shrimpe stated that it was his belief that the problem was due to a pipeline leak located somewhere between the Clark refinery and the Hartford/Wood River Terminal. Clark's line was never pressure tested to determine if any leaks were present (Hartford Underground Hydrocarbon Investigation, IEPA, 1990, Appendix A).

The 10-inch Sinclair line, previously identified, is owned by Sinclair and had been operated by ARCO until August 1990. Mr. Barry Bluth of Sinclair reported that the line had been abandoned since 1985, and initially contained approximately 600 barrels of unleaded gasoline to prevent corrosion. ARCO and Sinclair evacuated the line the week of August 27, 1990. Only 350 barrels were recovered, resulting in a shortage of approximately 250 barrels (10,500 gallons) of gasoline. Two pipeline pressure tests were conducted; one on August 31, and one on September 1, 1990, by Sinclair. The testing was observed by the United States Department of Transportation (US DOT) Office of Pipeline Safety. The pipeline integrity tests failed, indicating a leak in the line. Attachment 4 of Appendix A contains all the correspondence between IEPA, Sinclair, ARCO, and the US DOT regarding the Sinclair/ARCO line (IEPA, 1990).

VAPOR COMPLAINTS AND FIRES

Hydrocarbon vapor complaints, dating from 1966, have been documented from residents of the Village of Hartford. From 1966 to early 1970, all odor complaints received by the Hartford Police and Fire Departments were complaints about hydrocarbon odors. With few exceptions, the complaints have originated from residents living in the area north of Hawthorne Street, between Olive Street and Illinois State Highway 3. The affected area encompasses approximately one-tenth of a square mile.

On April 23, 1970, the first explosion and fire was reported to have occurred at the William Skaggs residence on 113 E. Cherry Street. After a series of house fires caused by ignited hydrocarbon vapors occurred during the years 1970 through 1978, an investigation into the cause of these fires was conducted. This investigation, described above, was completed in 1978 and was conducted by the IEPA, the Hartford Police Department, and an independent consulting firm, John Mathes and Associates, Inc. (Mathes), who was retained by Amoco, Clark, and Shell (Appendix C).

1978 Investigation into Methane/Hydrocarbon Odors in the Village of Hartford

In 1978, the Police Chief of Hartford, Mr. James Anderson, compiled a report summarizing vapor complaints from Village residents. This report included a chronological log documenting the complaint incidents and activities of 1978. A copy of this report is included in Appendix C.

Hartford Police and Fire records (Appendix D) and records kept by Clark Oil document complaints from Hartford residents concerning hydrocarbon odors. These records were examined by the Police Chief of Hartford during the compilation phase of report preparation. Complaints had been documented since the year 1966. Hydrocarbon odor complaints are dated May 1966, February 1968, July 1969, April 1970, and May 1970. The first explosion occurred on April 23, 1970, at 113 East Cherry Street, at the home of Mr. William Skaggs. More hydrocarbon odor complaints were recorded from residents during March and June 1973. Another fire occurred on March 13, 1973, in Mr. Don Tinnon's home at 119 West Date Street, the result of hydrocarbon vapors seeping into the basement. Odor complaints were received from residents during January, February, March, and October 1974. Additional complaints from residents were reported in April and May 1975, including a fire on May 28, 1975, at Mr. Robert Mays' home at 119 East Watkins. There are no recorded hydrocarbon odor complaints for the years 1967, 1971, 1972, 1976, and 1977.

In 1978, there were 76 odor complaints recorded from 60 homeowners during the months of March, April, and May. A total of 44 complaints were from residents living in areas located at the north end of Hartford on West Birch, West Cherry, West Date, North Olive, North Delmar, and West Watkins streets. The remainder of the complaints were reported from people living along East Maple, East Watkins, East Forest, East Date, and along the 500 block of Olive Street.

Five fires occurred in March 1978 that were caused by hydrocarbon vapor ignition in house basements:

- March 24, 1978 - 119 West Birch Street at Ms. Rinda Rambo's home.
- March 27, 1978 - 117 West Birch Street at the home of Mr. Hugh Morse.
- March 30, 1978 - 105 West Cherry Street at the home of Mr. Ken Whalen.
- March 25 and 29, 1978 - two fires at 118 East Date Street at Mr. Gene Overton's home.

During the second week of April 1979, four more fires occurred that were caused by hydrocarbon vapor accumulation that occurred after a 5-inch rain. However, official records concerning these incidents were not available. These reported fires were briefly mentioned in a Shell report issued in 1983 (Appendix E).

Police and Fire Department Records: 1981 - 1990

Since 1978, detailed records of hydrocarbon-related complaints made by Hartford residents have been kept on file by the police and fire departments in Hartford. In July 1981, there was one odor complaint reported from the Woodrow Wilson Gymnasium and a house fire occurred at 102 East Cherry at the home of Mr. Harold Settles.

During 1982, two vapor complaints were received from residents during March and November. Two additional complaints were filed in the months of April and May 1983. Only one complaint was filed in 1984, during the month of May. In 1985, two vapor complaints were made by residents to the Hartford Police or Fire Department during February, and a house fire was reported in June. The fire occurred at Mr. Noah Greer's home at 501 North Olive Street on June 11.

One complaint was reported during each of the months of February 1986, July 1987, and June 1988. No complaints were filed during 1989.

Figure 5 depicts the locations of homes with reported hydrocarbon odor complaints documented since 1981.

A severe, two year drought began in 1988. The drought ended in 1990, and hydrocarbon odor complaints from Hartford village residents began again. On March 21, 1990, one odor complaint was filed by a Hartford resident. On the same day, hydrocarbon vapors at Mr. Harold Settles' home at 102 East Cherry Street ignited twice within four hours.

Hydrocarbon odor complaints were reported again during May 1990. Twenty-seven vapor complaints and four fires are on record for May 1990. All of the fires occurred within four days of each other, and after heavy rains fell during May 16, 1990:

- May 16, 1990 - 117 East Forest Street at the home of Mr. Doug Neal.
- May 16, 1990 - 119 West Birch at Ms. Laurie Carnes' home.
- May 19, 1990 - 117 East Forest Street at Mr. Doug Neal's home. There was evidence that another fire had occurred, but that fire was apparently not officially reported.
- May 20, 1990 - 101 East Birch Street at the home of Mr. Jeff Bartlett.

During June 1990, 17 more vapor complaints were filed with the Hartford Police and Fire Departments. Thirteen of these complaints were filed by Ms. Jaunita Treadway of 119 West Date Street.

Table 2 lists all hydrocarbon-related fires in the Village of Hartford. Figure 6 shows all homes that have suffered reported fires since 1970. Any reports filed after June 1990 are not included in this report.

HISTORICAL TECHNICAL PERSPECTIVE

Five basement fires reported during March 1978 by Hartford village residents were caused by hydrocarbon vapor accumulation and ignition. In response, the IEPA launched detailed investigations into the cause of the house fires. In April 1978, 10 soil borings were drilled and completed as monitoring wells by the IEPA. These wells are now known as the EPA-series wells.

At the suggestion of the IEPA, Hartford officials invited Amoco, Clark, and Shell to voluntarily cooperate in an investigation of the subsurface hydrocarbon contamination beneath the village of Hartford. John Mathes & Associates, Inc. (Mathes), an environmental consulting firm, was retained by Amoco, Clark, and Shell to investigate possible causes for the solutions to the problem of hydrocarbon vapor accumulation in the village of Hartford. A Phase I investigation report was issued by Mathes in 1978. A summary of the data collected is given below and a copy of this report is included in Appendix F.

1978 MATHES REPORT

The Phase I Investigation Report issued by Mathes documented an initial investigation to determine the source and cause of the presence of hydrocarbons in the subsurface soils beneath the village of Hartford. The Phase I investigation report included a summary of the data collected by the IEPA and by Shell Oil Company:

- results of the soil gas survey conducted by the IEPA in the vicinity of Hartford during March 1978
- soil sampling and logging results obtained from 10 recent soil borings
- the results of groundwater analyses from samples obtained from both public water supply wells in the area and from 12 monitoring wells installed by the IEPA and Shell Oil Company
- the results of testing and characterization by chromatographic analysis of the gasoline products refined at the three facilities located near Hartford
- piezometric maps obtained by monitoring groundwater elevations and product thickness in the 12 newly installed wells in the vicinity of Hartford
- product sampling and analysis of samples obtained from three monitoring wells
- results of air sampling and analysis at three locations in Hartford.

The IEPA and Shell Oil Company gauged and sampled the 12 newly-installed monitoring wells during 1978. Three wells sampled contained from 3 to 11 feet of separate-phase product detected as gasoline. Additional wells contained hydrocarbon product with a boiling point higher than gasoline. Three more wells contained traces of gasoline. The gasoline identified from the three wells with separate-phase product was tested for lead alkyl. The organic lead antiknock additive, tetraethyl lead (TEL), was present in the samples tested (Mathes, 1978).

Geologic and hydrogeologic conditions were also addressed and summarized for the Hartford area in the report issued by Mathes in 1978. The regional geology of the area was described as "recent alluvium which is underlain by older alluvial deposits beneath which are glacial valley train materials" (Mathes, 1978). The alluvium was postulated to be approximately 75 feet thick. Glacial outwash beneath the alluvium was postulated to be approximately 65 feet thick. Hydrogeologic conditions beneath Hartford were described by Mathes as both "leaky artesian" and "water table" conditions, depending on the lithology of the aquifer.

Under natural conditions, the groundwater flow direction beneath Hartford would be toward the Mississippi River to the west. However, large quantities of groundwater have been removed at the facilities owned by Amoco and Shell Oil Companies. The effect of this pumping has been the development of pronounced cones of depression beneath each facility. This, in turn, causes the groundwater in the vicinity of Hartford to flow from virtually all directions toward these cones of depression. Figures VII through XII, and Figure XIX of the 1978 Mathes Phase I Investigation Report (Appendix F), illustrate that the direction of groundwater flow in the vicinity of Hartford has been in a northeasterly direction since at least the year 1951.

Geologically, a thick, continuous layer of clay that increases in thickness to the east beneath Hartford was identified in the Mathes report. The thickness of the clay increases dramatically from west to east, and water levels measured in wells east of the village are above the base of this clay. The near-surface aquifer may potentially become confined in this area (Mathes, 1978). In addition, the thick clay layer east of Hartford may retard the rate of gasoline migration, since gasoline floats on water, and this clay layer appears impermeable. The clay layer may act as a barrier to gasoline migration, which normally would move to the northeast with the direction of groundwater flow. The clay barrier may trap hydrocarbons, and this entrapment may result in the distribution of reported hydrocarbon vapor complaints and house fires (Mathes, 1978).

METHANE INVESTIGATION

Possible sources of methane gas production in Hartford were investigated in 1978 by the Illinois State Geological Survey (ISGS) at the request of the IEPA. The ISGS obtained air samples from the basement of the Woodrow Wilson High School located at Delmar and Rand Avenues in Hartford. The ISGS issued a report on July 12, 1978, that addressed potential sources of methane production. This report is included as an attachment to the report issued by Shepherd in 1983 (Appendix E).

The chemical composition and radiocarbon age of the methane detected in the air samples collected may indicate potential methane sources. The chemical composition of the air sample collected was determined using a gas chromatograph. The air sample submitted was found to contain over 40 percent methane. The radio-carbon age of the methane from the sample collected at Hartford was 27,300 ± 1,500 years. The exact source of methane production in the Hartford area could not be determined by the ISGS. However, the following potential sources of methane were eliminated:

- sanitary landfills
- sewage disposal plants
- natural decomposition of river sediments
- coal gas
- glacial drift gas.

The sample collection during this investigation did not contain ethane, a component of natural gas. The lack of ethane in the sample tends to rule out a natural gas pipeline leak as a source of the methane gas under investigation. The stated conclusion of this report was that the chemical and isotopic data were most similar to petroleum-related gas associated with oil production wells south and southeast of Hartford.

1983 Shepherd Report

Mr. William D. Shepherd, Shell Senior Staff Engineer of Environmental Affairs, performed a geohydrological site assessment of the Wood River Manufacturing Complex (WRMC) in 1983. The assessment report issued (Appendix E) included information regarding Shell's involvement in the 1978 Phase I Investigation Report issued by Mathes. Mr. Shepherd estimated that one million gallons of product underlies Hartford in an area 500 feet by 2,000 feet. Included in this report was a groundwater gradient map (Plat 5, Appendix E) that shows a northeast groundwater flow direction. An isopach map of product thickness was superimposed on the groundwater gradient map and was included as Plat 6 of the report (Appendix E). This map showed a groundwater plume of hydrocarbons in the uppermost aquifer beneath Hartford between Arbor and Watkins Streets migrating northeast beneath Olive Street.

Shepherd illustrated that a good correlation existed between the downgradient plume location and reported hydrocarbon releases from the Clark pipelines on Elm Street that are hydraulically upgradient of the plume. These maps were constructed from gauging data acquired on May 2, 1978 (Section 2, Appendix C). In addition, product recovery data through 1982 were tabulated. According to Clark, 639,022 gallons of product had been recovered by June 1982.

RECENT INVESTIGATIONS

The release of unleaded fuel from an underground pipeline owned by Shell near Rand Avenue on December 16, 1989, prompted new investigations into the lithology of the subsurface and groundwater contamination conditions beneath northern Hartford. Since December 21, 1989, a total of 38 additional wells were installed by Shell northeast of the Village of Hartford. Cone penetrometer testing was also conducted to profile the lithology of the subsurface in the immediate vicinity of the Shell release. Additional information was provided by five soil-gas surveys conducted to delineate plume extent and vapor migration patterns. Four of the soil-gas surveys were conducted by ES at the request of Shell, and one was conducted by Mathes at the request of Clark. In addition, an aquifer performance test was conducted in May 1990, in the area of the Rand Avenue pipeline release. The data collected during this testing provided an estimation of the hydraulic properties of the aquifer system at the Rand Avenue release site. Soil testing for geotechnical parameters related to aquifer hydraulics was also recently performed on soils sampled at depths below the area of the Shell pipeline release. The results of the aquifer performance and soil testing will be discussed in Section 6 of this report.

SP WELLS

As an emergency response to the Rand Avenue release, ES was retained by Shell to install a series of monitoring wells (SP-series wells) to delineate the extent of hydrocarbons in the subsurface. The drilling activities were conducted in three phases:

- Phase I - six wells (SP-1 to SP-6) installed between December 21-29, 1989 (Appendix G);
- Phase II - 12 wells (SP-7 to SP-18) installed between January 8-14, 1990 (Appendix G); and
- Phase III - eight wells (SP-19 to SP-26) installed March 19-23, 1990 (Appendix H).

The drilling of the 26 SP wells described above identified two sand lenses beneath Hartford that are stratigraphically above the Main Sand. Figure 1 of Appendix H depicts the location of the SP-series wells. The uppermost sand unit is referred to as the Rand Sand. Underlying the Rand Sand, and separated from it by 5 to 11.5 feet of clay, is the sand unit known as the EPA Sand. Below the EPA Sand, and separated from it by 2 to 3.5 feet of clay, is the Main Sand.

Twenty-one SP-series wells were completed in the Rand Sand during the initial three phases of investigation. Six of these wells, when gauged in 1990, were found to contain separate-phase product. Five SP wells, screened across the EPA and Main Sand, have not shown separate-phase hydrocarbon under both unsaturated and saturated conditions, indicating that the product is confined to the Rand Sand. After to these initial site investigations, well SP-2 was plugged and replaced by well SP-2B. This well was installed during October 1991, and is screened only across the EPA sand interval (Appendix I).

Groundwater investigations, conducted during the initial investigation phase, indicated that the groundwater in the Rand Sand was flowing in a northeasterly direction, away from Hartford. Figures 2 and 3 of Appendix G illustrate the direction of flow in the Rand Sand to be to the northeast. These figures also illustrate that six of the eight wells that contained product on January 16, 1990, are downgradient of the Shell pipeline rupture site.

CONE PENETROMETER TESTS

On January 29, 1990, ES conducted a cone penetrometer test (CPT) survey at the Rand Avenue release site to evaluate site lithology. A report summarizing field activities and data interpretation is located in Appendix J. A total of 24 CPTs were performed, as shown in Figure 1 of Appendix J. These tests were performed to investigate the potentially discontinuous nature of the Rand Sand and to determine if the migration of released product was controlled by sand geometry.

Results of the CPT analysis showed that the Rand Sand becomes fine grained and decreases in thickness to the east. Further evidence indicates that the Rand Sand does not extend far beneath Amoco's property to the north. Another unnamed sand unit was found to overlap the Rand Sand to the northeast; however, it is not a water-bearing unit in this area. Figures 6 through 14 in Appendix J profile the Rand Sand in cross-section and plan view.

Deep CPT logs (5, 11, 13, 14, 19, and 21) demonstrate the EPA Sand is present in the area and is separated from the Rand Sand by a layer of clay varying in thickness from 5 feet to 11.5 feet. The deepest CPT logs (5 and 21) also show that the EPA Sand is a separate sand from the underlying Main Sand at the Rand Avenue release site (Figures 7 and 13 in Appendix J). The thickness of the clay between the EPA and Main Sands at these two locations (CPT logs 5 and 21) ranges from 4.1 to 4.9 feet.

P WELLS

Separate-phase product was detected in the EPA-7 well on January 21, 1990. In response, ES drilled six monitoring wells to determine if the hydrocarbons detected in the EPA-7 well were related to the Rand Avenue release. A report summarizing field activities and hydrogeologic conditions is presented in Appendix K. Figure 1 of Appendix K depicts the location of the EPA well and the six investigative wells (P-76 through P-81) installed on the Shell Tannery property.

The Rand and EPA Sands were both present in the boring performed at the P-76 well location, and the well was subsequently screened across the EPA and Main Aquifers (sands). The remaining wells, P-77, P-78, P-79, and P-80, were screened exclusively at the top of the Main Aquifer. As an offset to well P-80, well P-81 was screened solely across the EPA Aquifer.

Well P-81, screened solely in the EPA Sand, was the only well in which separate-phase hydrocarbons were observed. Water samples from P-77, P-78, P-79, and P-80 had definite hydrocarbon odors, but no separate-phase product. Analysis of the product sampled in well P-81 indicated that it was a mixture of diesel fuel, kerosene, and gasoline. The hydrocarbon found in this well is not the same as the hydrocarbon found in P-105 (an offset to EPA-7) or any of the SP-series wells at the Rand Avenue site. The well located closest to the Rand Avenue release site, P-76, was found to have no separate-phase product or odor, suggesting that hydrocarbons found in wells located south of well P-76 and, therefore, farther away from the Shell release area (wells P-77 through P-81), originated from another source. Separate-phase hydrocarbons were observed only in the EPA Aquifer at well P-81. However, soluble hydrocarbons were present in the Main Aquifer in all wells with the exception of well P-76.

At the request of Shell, on April 2, 1990, ES installed four additional wells (P-104 to P-107) on the Shell Tannery property to investigate the source of separate-phase product detected in well EPA-7. A report summarizing field activities is located in Appendix L. Since well EPA-7 is screened across a water-bearing silt zone, and both the EPA and Main Sands, three wells (P-104, P-105, and P-106) were completed as cluster wells next to EPA-7 to determine which aquifer(s) contained the product that had been detected on January 21, 1990. The fourth well (P-107) was completed in the EPA Sand next to Well P-79, which is screened in the Main Aquifer. Figure 1 of Appendix L depicts the location of these wells.

Cluster well P-104 was screened in a 1.5 foot, water-bearing silt zone at a depth of 22 feet below grade. No evidence of hydrocarbons was detected in the water samples collected from this well. However, P-105, screened in the EPA Sand, was found to have a strong hydrocarbon odor. To complete the well cluster, P-106 was screened at the top of the Main Aquifer. No separate-phase product was observed in this well, although headspace analysis for volatile organics of soil samples taken during drilling indicated the presence of soluble hydrocarbons.

Well P-107 was installed and screened in the EPA Sand to detect the presence of hydrocarbons, if any, north of the EPA well. No separate-phase product was observed, nor did headspace analysis of soil samples collected indicate any volatile organics present.

Figure 7 is a map that identifies the location of the monitoring wells installed in the vicinity of Hartford. These wells were gauged for separate-phase product April 18, 1990 (Table 1 of Appendix L). Product was observed in P-105.

SOIL-GAS SURVEYS

Four soil-gas surveys were performed by ES at the request of Shell at the Rand Avenue site during 1990. Two surveys were performed to define the presence and extent of a vapor plume as a result of the Rand Avenue pipeline break in December 1989. Two surveys were performed west of the Rand site to investigate a potential vapor plume resulting from a Shell pipeline break in 1973 documented with records summarized in Appendix B.

April 1990 Survey

The first soil-gas survey conducted by ES was performed in April 1990. The report documenting the results of this survey is located in Appendix M. Mathes and Associates, Inc., was contracted by ES to perform the field work. The purpose of the survey was to determine if vapors from the Rand Avenue release were migrating through the trench fill of a buried sewer. Depth to the top of the sewer was 15 feet. Location of the sewer is immediately south of the release site, and it runs parallel to Rand Avenue.

A total of 25 soil-gas samples were taken during this project. Twenty-one samples were collected from and adjacent to the sewer trench fill. Four samples were taken north of the sewer. Sample depths ranged from 10 to 15 feet. The results of the survey show that two locations in or near the trench fill had vapor concentrations of more than 1 part per million volume (ppmv) BTEX (benzene, toluene, ethyl-benzene, and xylene). These two sample locations were PH-15 and PH-17. Total BTEX found was 1.0 ppmv and 8.8 ppmv, respectively. Five additional samples were taken in the immediate vicinity of these two locations. All confirmation samples contained less than 1 ppmv BTEX.

Additional sampling in the trench fill revealed that soil-gas vapor concentrations decreased to the west, away from the release site. The results from this survey suggest that the sewer-trench fill was not, and is not, acting as a conduit for the migration of vapors from the Rand release site.

June 1990 Survey

A second soil-gas survey conducted by ES was initiated on June 5, 1990 (Appendix N). The area of investigation was located west of the Rand release site. The survey was not totally completed because of rain that occurred during the second survey day. The elevated water table produced ambiguous test results. This survey was later completed on October 29, 1990.

October 1990 Survey

The intent of this soil-gas survey (Appendix O) was to define the location of a possible product plume from an earlier Shell pipeline break that occurred in 1973. This pipeline break is described in a report located in Appendix B. Eighteen locations were sampled during this project. Long sample-extraction times indicated that the subsurface soils west of the Rand site were primarily clays and silty clays. Extracted water samples from these locations also contained a large amount of silty clays.

Vapor headspace tests were performed on water samples where the soil lithology appeared to be clay or silty clay and the conventional soil-gas results were suspected to be misleading. By running a headspace test on the collected groundwater, an indication of the volatiles present could be determined. Vapor headspace testing of the groundwater was observed to decrease west of the Rand Avenue site, except at location SB-Q. This location is north of the intersection of Rand Avenue and North Olive Street. A water sample was collected from the SB-Q location, and a brown, weathered, separate-phase hydrocarbon layer was observed. The hydrocarbon is believed to have originated from an earlier Clark Oil pipeline leak that occurred in the vicinity of Rand Avenue and North Olive Street. This leak is documented in the 1978 Investigation Into Methane/Hydrocarbon Odors conducted by the Hartford Police Department (Section 2, Appendix C).

The presence of vapors associated with this leak are confirmed by a soil-gas survey conducted by Mathes in June 1990 (Appendix P). Figure 8 is an isopleth concentration map of volatile organics detected during the soil-gas survey conducted by Mathes, and Figure 9 is an isopleth concentration map of the same data contoured by ES. Figure 9 was developed by taking into consideration the location of known hydrocarbon releases. At the intersection of Rand Avenue and North Olive Street, at sample point PH-13, 994 ppmv total petroleum hydrocarbons (TPH) was measured at a depth of 10 feet (Figures 8 and 9). During the October 1990, soil-gas survey, performed by Engineering-Science, 730 ppmv TPH was recorded from headspace tests of the groundwater at location SB-Q, located north of the intersection of Rand Avenue release and North Olive Street. Isopleth mapping of the volatile concentrations obtained from the October soil-gas survey conducted by ES (Figure 5, Appendix O) shows that the concentration of volatiles decrease to the west from the Rand release site until the intersection of Rand Avenue and North Olive Street. At this location, vapor concentrations were observed to increase.

Preliminary field work during 1978, in the area of the Clark pipeline releases, consisted of hand augering a boring to a depth of 10 feet, then taking vapor readings using an explosimeter. The explosimeter indicated 100 percent hydrocarbon vapor saturation. Consequently, five groundwater monitor wells were installed in this area (Wells B-19, B-19A, B-19B, B-39, and B-39A). According to well-gauging data on file, three wells contained a diesel hydrocarbon on August 7, 1978. These wells were B-39A, B-39, and B-19A. Based on screen depths and lithologies of the area, wells B-19A and B-39A are screened across the Rand Sand. Well B-19 was last gauged in November 1989, and was found to contain 3 inches of separate-phase product.

A report to Mr. Jerry Kennett (Clark Oil) from Gary Mathes (John Mathes and Associates), dated August 21, 1978 (Appendix Q), clearly states that hydrocarbons were known to be present in an area between North Olive Street and Rand Avenue and Market Street and East Birch Street. This report documents that product existed in the Rand Sand long before the Shell release of December 1989. Product found in two wells, B-19A and B-39A, and was described by Mathes as having the appearance of diesel fuel. Engineering-Science has mapped the southern limit of the Rand Sand, and Figure 10 illustrates that the Rand Sand is present in the area of Well B-19A.

It is not known how much product was lost from the Clark pipeline break, or if a recovery effort was made. However, hydrocarbons not associated with the Rand Avenue release have been documented in this area since 1978.

November 1990 Survey

On November 3, 1990, a fourth soil-gas survey was performed on the Shell Tannery property, located south of the Rand Avenue release site. The results of this survey are summarized in a report are located in Appendix R. Eight locations were sampled on the Tannery property and four locations were sampled in the trench fill of the buried sewer.

Two locations, SRT-A and SRT-B, on the Tannery property showed measurable concentrations of vapors. Further vapor delineation to the south, west, and northwest of SRT-A showed a decline in vapor concentrations. Sample withdrawal times indicated low permeability soils in areas north, west, and northwest of SRT-A and SRT-B. These long sampling times reflected a compositional change in the subsurface soils and a decrease permeabilities in these areas.

The four locations sampled in the sewer-trench fill were taken to investigate the results of the April 1990, soil-gas survey. Concentrations of vapors above 1.8 ppmv were not present at 10 and 15 feet below surface in the fill. Long sampling intervals also indicated that the fill used in the trench was probably a clay or silty clay with a correspondingly low permeability.

VAPOR MIGRATION FROM THE RAND AVENUE RELEASE

Results of the soil-gas surveys suggest that vapor migration from the Rand Avenue release site is impeded to the south, west, and northwest by clays and silty clays. Long sampling intervals required for obtaining a representative soil-gas sample in these areas supports the suggestion that the lithologies in these areas exhibit low permeability.

Artificial migration pathways for vapors were sampled, and it was concluded that vapors from the Rand Avenue release site were not present in concentrations that could contribute to the problems found in Hartford. Also, fill material used in potential vapor pathway investigated is composed of a clay or silty clay, and exhibits long sample extraction times.

Hydrocarbon vapors found west-southwest of the Rand Avenue release site may result from the reported Clark Oil pipeline break of 1978, near the intersection of North Olive and Rand Avenue. The report concerning the Mathes June 1990, soil-gas survey (located in Appendix P) documents that elevated vapor concentrations still exist near this break. The Engineering-Science October 1990 (Appendix O) soil-gas survey identified separate-phase product in this area. Isopleth mapping of the vapor readings obtained during the October 1990 survey show that soil-gas vapors decrease to the west from the Rand Avenue release site until the area near the intersection of Rand Avenue and North Olive Street. Figure 8, from the Mathes

1990 Soil-Gas Survey, illustrates that the concentrations of Total Petroleum Hydrocarbon (TPH) vapors detected from depths of 7 to 10 feet below surface in this area are migrating to the south. Figure 9, a TPH concentration map based on the data collected by Mathes in 1990, incorporates the locations of documented pipeline breaks and product releases. The TPH concentration of 994 ppmv at the Mathes soil-gas sample location PH-13 indicates the location of a hydrocarbon vapor plume associated with the 1978 fuel oil release from a Clark line near Rand Avenue.

Based on weekly groundwater elevation data (Figure 11) at the Rand Avenue release site and the information gathered from the soil-gas surveys, it is not likely that vapors associated with the Rand Avenue release site are migrating toward Hartford. The cone-of-depression maintained at the Rand Avenue site controls groundwater and, hence, potential vapor migration. Soil-gas survey results indicate that soils with low permeability exist to the south, west, and northwest of the Rand site. These low permeability soils provide a barrier to vapor migration. In addition, groundwater movement and associated potential vapor migration is to the north-northeast of the release site, away from the village of Hartford.

PRODUCT RECOVERY

HARTFORD

A recovery well (RW-1) was installed east of Delmar Avenue at Forest Street in Hartford on June 14, 1978, by Clark Oil Company. The recovery well was installed into the Main Sand and was gravel-packed to a depth of 45 feet. A skimmer pump was installed in the well to recover hydrocarbon product. The skimmer pump does not lower the groundwater level (create a drawdown) for product collection; hence, only separate-phase hydrocarbons that float into the well can be withdrawn. Such a system is nominally effective because it is dependent on a fluctuating water table and precipitation influences. A second product-skimming recovery well (RW-2) was installed by Clark in 1979, west of Olive Street between Date and Cherry Streets. The locations of these recovery wells may be seen in Figure 7, the well location map of the Hartford area.

The final page of Appendix E lists monthly product recovery figures reported by Clark between July 1978 and June 1982. At that time, Clark had reportedly recovered 639,022 gallons of gasoline from beneath the village. Monthly product recovery rates from both wells ranged from 1,091 gallons to 28,789 gallons. According to the IEPA (Appendix A), Clark had reportedly recovered a total of 1,161,981 gallons of product from the vicinity of Hartford by 1990.

RAND AVENUE SITE

The initial recovery system at the Rand Avenue release site consisted of air-actuated pumps installed in nine recovery wells to withdraw collected product. Air-activated pumps inject air into the well chamber, which forces accumulated fluids to the surface. These fluids are then collected in an oil-water separator, which separates the product from the water. In the oil-water separator, the product layer releases over a baffle into a collection tank. The recovered water is pumped to the Shell waste treatment facility for treatment. The system recovered product only when water table elevations were low and when product could freely enter the well bores. Generally, this occurred only during the dry months, as expected; most notably during the summer.

Product recovery at the Rand Avenue release site has been hampered by fluctuating water levels in the perched saturated zone (Rand Sand). When water levels rise above the Rand Sand, product disappears from the well bore because the hydrocarbons become trapped below the water surface in the gravel-packed, annular space of the well and in the soils above the Rand Sand interval. This is because the soils above the Rand Sand are low permeability clays and silty clays.

The aquifer performance test completed at the site during April 1990 (Appendix S) showed that as the water table was drawn down by pumping, the amount of product collected in the observation wells increased. This was measured by determining product thickness in the affected observation wells. With increased drawdown, hydrocarbons drained from the low permeability soils and filled the space previously occupied by the water.

Based on the results obtained during aquifer testing, the product recovery system at the Rand Avenue release site was upgraded in late April 1991. Three wells, two 8-inch diameter and one 4-inch diameter, were equipped with submersible groundwater pumps. These wells are currently used as drawdown wells to create a cone-of-depression in the Rand Aquifer. This drawdown action facilitates product recovery.

Figure 11 is a map of the cone-of-depression created by the pumping action in the Rand Sand. Nine wells, located within the influence of the cone, contain air-activated, product-recovery pumps. Each pump is set on a timer, which allows the pump chamber to fill with product and water. After a programmed period of time has elapsed, air is injected into the chamber, forcing the fluids to the surface. At the surface, the fluids travel to an oil-water separator. As the product layer increases into the oil-water separator, the product releases over a baffle plate and is transferred to a holding tank. Water is then periodically drawn from the base of the separator, and recovered product is skimmed off the tank surface. The water recovered is pumped to the waste treatment facility operated by Shell. As of July 30, 1991, the system has recovered 2,455 gallons of product.

GEOLOGIC/HYDROGEOLOGIC CONDITIONS

GENERAL DISCUSSION

The bedrock of the American Bottoms is a stratigraphic unit consisting of Pennsylvanian limestones to the east and Mississippian limestones to the west. These rock units were deposited some 350 million years ago. Four cycles of uplift and erosion, during Tertiary Era, established drainage patterns in essentially their modern form, and cut the American Bottoms valley to nearly its present configuration. Commonly, bedrock now occurs between 110 and 170 feet below land surface in the valley area.

During the Pleistocene period, the valley was filled with sandy glacial outwash known as the Mackinaw Member of the Henry Formation. The sands are remnants of the Wisconsinian glaciation during the Pleistocene period 10,000 years ago. This glacial outwash was carried by streams as much as 75 miles beyond the margin of the active glacier, but was confined within the valley walls (Shepherd, 1983; Appendix E). The sands of the Mackinaw range from 60 to 150 feet in thickness and compose what is frequently referred to in this report as the Main Sand (Main Aquifer).

The uppermost geologic unit is the Cahokia Alluvium of Holocene Age, which consists of sands, silts, and clays of floodplain, channel, and modern river origin. In Recent Times, the Mississippi River "...has scoured and reworked the upper part of the valley fill in migrating across the broad bottomlands. At the same time, spreading floodwaters deposited silt and clay along the sides of the channel and in backwater areas. The channel migration, cut-and-fill, and flooding have produced complex, heterogeneous deposits" (Shepherd, 1983; Appendix E). It is here, in the Cahokia Alluvium, that the Rand Sand is found.

The valley fill material (Main Sand) is the primary source for large-quantity water production in the area. Because it is composed of alluvium and glacial outwash, the hydraulic capacity of this unit is high. Natural groundwater movement beneath the American Bottoms is westerly, draining from the limestone bluffs (east wall of the valley) to the Mississippi River. However, for the past 70 years, the natural movement of groundwater has been altered in the Hartford vicinity due to large-scale water pumpage. Known cones of depression flank the village to the north (Amoco) and northeast (Shell). These cones of influence are illustrated in Plat 4 of Appendix E. The net effect of this drawdown is groundwater movement to the northeast. Figures VII through XII of Appendix F, and Plat 5 of Appendix F illustrate historical groundwater movement beneath Hartford.

Product was released from a Shell pipeline located along Rand Avenue in Hartford on December 16, 1989. In order to determine the extent and location of released product and the lithology of the subsurface in the vicinity of the release, 36 soil borings were performed and 24 cone penetrometer test logs were acquired. A total of 33 groundwater monitoring wells have been installed, within the soil borings completed, to monitor shallow groundwater conditions. A map illustrating the location of these wells is shown in Figure 7.

Based on the investigations conducted to date, the hydrogeology of the Hartford vicinity consists of three aquifers that vary from unconfined to confined conditions. The aquifers consist of coarse to fine-grained, permeable sands deposited within fairly impermeable, silty clays. The thickest aquifer is known as the Main Aquifer and it was deposited as sandy glacial outwash (valley fill material). This aquifer underlies the entire area beginning at depths ranging from approximately 20 to 45 feet below land surface. The Main Aquifer is composited of coarse to fine-grained, permeable sands ranging from 60 to 150 feet in thickness and is the primary source for large-quantity water production in this area.

Overlying the Main Aquifer, beneath the northeast section of Hartford, are two sand intervals interbedden with fairly impermeable clay and silty clays. The upper, seasonally saturated sand interval, encountered approximately 20 feet below ground surface, is locally known as the Rand Sand. The southwest boundary of the EPA Sand has been defined by drilling and subsurface investigations; it is separated from the Rand Sand by a clay layer that ranges in thickness from 3 to 11.5 feet.

The lithologic and hydraulic characteristics of the Rand, EPA, and Main Sands were investigated by soil sampling and analysis of soil boring logs, cone penetrometer testing (CPT), aquifer performance testing, slug testing, and geotechnical soil sampling and laboratory testing. The results of these investigations will be summarized below. The stratigraphy of the area under investigation, described above, is illustrated by the geologic cross-sections developed by ES shown in Figures 13 through 17. The cross-sections are designated as illustrated in Figure 12.

The Main Sand

The Main Sand (or Main Aquifer) is the name applied to the water-bearing unit of the Mackinaw member of the Henry Formation. The hydrogeologic characteristics of the Main Sand have been investigated in area around Hartford with the drilling and installation of numerous groundwater monitoring wells. These investigations were completed in several phases, beginning with the installation of the designated EPA-series wells.

The EPA-series wells were completed by Mathes during a Phase I site investigation in 1978. The boring logs completed during this Phase I investigation (Appendix F) document the lithologic character of the Main Sand. The Main Sand is fairly thick, and, based on these initial borings, consists of fine-to-coarse-grained sands with some gravel.

Mathes performed the Phase II investigation, and 35 soil borings were completed as monitoring wells, designated as B-series wells. The location of these wells are shown in Figure 7. The wells were constructed to investigate groundwater conditions in the Main and EPA Aquifers. The subsurface stratigraphy, developed by Mathes, is illustrated by the geologic cross-sections of Figures 18, 19, and 20. The morphology of the upper surface of the Main Sand is illustrated by these cross-sections.

The majority of the wells installed during this Phase II subsurface investigation have been plugged and abandoned, destroyed, paved over, or have generally become inaccessible. As a result, these wells are not currently used to monitor groundwater conditions.

The configuration of the top of the Main Sand is illustrated by the structure map shown in Figure 21. The top of the Main Sand map was based upon the geologic relationships displayed by the geologic cross-sections developed by Mathes and illustrated in Figures 18 through 20. In addition, the elevation of the Main Sand was also determined at two CPT locations: CPT-5 and CPT-21B. Table 3 summarizes the elevation at the top of the Main Sand for those wells used to construct the structure map shown in Figure 21.

The map of the Main Sand (Figure 21) illustrates that the top of the Main Sand dips to the northeast and appears gently rolling. An anticlinal features centered at the EPA-6 well location is present at depth beneath the village of Hartford. The top of the Main Sand varies in depth from 20 feet below surface at EPA-2 well (410.10 feet above sea level) to 48 feet below surface at CPT-21B (383.67 feet above sea level). The rate of change (gradient) at the top of the Main Sand, calculated from these two data points, is 37.6 feet per mile. The direction of dip at the top of the Main Sand is toward the northeast.

The location of the pinchout of the clay that separates the EPA and Main Sands is shown in Figure 21. The areal extent of this clay layer is also shown by a cross-hatched map pattern on Figure 21. As shown on cross-sections B-B' and E-E', displayed in Figures 14 and 17, this clay layer maintains a consistent thickness in the northeasterly direction beneath the village of Hartford.

The potentiometric surface of the Main Aquifer corrected for product thickness is shown in Figure 22. The groundwater elevation data used to construct this map was collected during the Third Quarter of 1990, and is summarized in Table 3. Product thicknesses were corrected using an accepted 80 percent density factor. Wells gauged and included on this potentiometric surface map were constructed so that only the Main Sand interval was monitored. As can be seen from this map, groundwater flows in a northeasterly direction at a gradient of 0.0018 feet per foot.

The potentiometric surface of the Main Aquifer, not corrected for product thickness, is shown in Figure 23. The uncorrected groundwater elevation data used to construct this map is also summarized in Table 3. Approximately 5 feet of product was gauged in well B-32. Since hydrocarbon product (gasoline) floats on top of water, the result of using uncorrected groundwater elevation data is an apparent lowering of the top of the groundwater surface. The uncorrected potentiometric surface map in Figure 23 illustrates this effect with an apparent groundwater depression centered at the B-32 well location. The apparent groundwater depression represents the location of an accumulation of hydrocarbon product in well B-32.

Product accumulation, evident in well B-32, is apparently caused by the intersection of the clay layer separating the EPA and Main Aquifers and the water table. The movement of product, as it floats on the water table, is restricted by the fairly impermeable clay layer. Product migration is restricted, and hydrocarbons are trapped by the clay when the water table is below the top of this clay layer. This phenomenon was initially recognized by John Mathes & Associates during the Phase I Site Investigation conducted in 1978 (Appendix F).

Hydrocarbon product has been detected and documented in the Main Sand beneath Hartford since the initial subsurface investigations conducted by Mathes in 1978. Copies of the initial interpretive groundwater elevation and product thickness maps developed by Mathes are presented as Attachments (Plat 5 and 6) to the report issued by Shepherd (1983) located in Appendix E.

The Phase II investigation conducted by Mathes included the measurement of groundwater elevations and product thickness in over 35 monitoring wells (EPA and B-series wells). A product thickness map was issued by Mathes in 1982 and was based on this data. This product thickness map is included as Figure 24 of the report issued by Shepherd in 1983 (Appendix E). This figure illustrates that the maximum accumulation of product occurs in the Main Aquifer beneath the intersection of Market and Elm Streets in Hartford. In addition, an isolated product accumulation area in the Main Sand is apparent beneath the intersections of Olive and Elm Streets.

Table 1 of this report summarizes the documented locations of product releases in the vicinity of Hartford. Comparing Table 1 and the product thickness map described above (Figure 24; Appendix E), it is recognized that the greatest product accumulation area correlates with the locations of documented releases from the Clark and Arco product lines.

The hydrocarbon thickness map, based on product thickness data collected during the third quarter of 1990 (Table 3), is shown in Figure 24 of this report. The thickness of hydrocarbons detected in 1982 can be compared to the hydrocarbon thickness data collected in 1990. The product plume caused by releases from the Clark and ARCO product lines near Olive and Elm Streets is again evident from the product thickness data collected in 1990. The product plume located beneath Cherry and Market Streets is evident on both the 1982 and 1990 hydrocarbon product thickness maps. However, the primary hydrocarbon accumulation area evident in 1982 (in the Main Sand beneath the intersection of Elm and Market Streets) is not detected from the data collected in 1990. Unfortunately, many observation wells monitored in 1982 in this area are no longer accessible. The plume in this area can therefore no longer be defined.

The hydraulic properties of the Main Sand beneath the Main Property of the Shell facility was investigated during the performance of two slug tests conducted by ES during 1991 (Appendix T). The results of these slug tests indicate the hydraulic conductivity (K) of the Main Aquifer at two separate depths. Nested wells P-85C and P85D, screened at 76.0 to 79.0 and 97.0 to 99.0 feet below surface, respectively, were used to determine the required values of hydraulic conductivity. The parameter of hydraulic conductivity is a measure of the permeability of a porous media. In the area of the Main property of Shell, the K values of the Main Sand range from 255.2 to 467.7 gpd/ft^2. This means that, on the average, approximately 350 gallons of water percolate during a one-day period through a square foot area of the aquifer.

The EPA Sand

The EPA Sand, when present, is encountered within the upper 20 feet of the Main Sand and is separated from the Main Sand by a clay layer that ranges up to 5 feet thick. This clay layer pinches out beneath Hartford as illustrated by the stippled map pattern evident in Figure 21. As shown on cross-sections B-B" and E-E", illustrated in Figures 14 and 17, this clay layer maintains a consistent thickness, when present, north of the village of Hartford. The EPA Sand is approximately 7 feet thick and is in apparent hydraulic communication with the Main Sand in the area where the separating clay pinches out.

Figures 25 and 26 illustrate the morphology of the upper and lower surfaces of the EPA Sand. These maps are based on lithologic data collected during the installation of monitoring wells in the Hartford area. The lithologic data displayed was obtained during the 1978 initial investigation conducted by Mathes and the recent subsurface investigations completed by ES for Shell in 1991.

Figure 27 is an isopach map illustrating the thickness of the EPA Sand. This map is based on lithologic data collected during subsurface investigations conducted through 1991. The EPA Sand becomes a part of the Main Sand when the intervening clay layer pinches out. The stratigraphic relationship between the EPA and Main Sands are illustrated by the maps shown on Figures 21 and 25-27, and the stratigraphic cross-sections shown on Figures 14 through 17.

A review of the boring logs for wells installed in the Hartford and Rand Avenue area shows that 17 wells appear to be partially or completely screened in the EPA Sand. Of these 17, a total of four wells are constructed to exclusively monitor the EPA Sand interval in the area of the Rand Avenue release site. These four wells are P-81, P-105, P-107, and a newly-installed Rand Avenue area well, SP-2B (Appendix I). The remaining wells in the vicinity of Hartford are constructed so that the well screen extends across the EPA Sand and into the Main Sand. Groundwater elevation data collected from only four monitoring wells are not sufficient to define the potentiometric surface of the EPA Sand.

Figure 28 is an isopach map illustrating product thickness detected in the EPA Sand during gauging and monitoring activities conducted during the third quarter of 1990. The data illustrated by Figure 28 is summarized in Table 3; less than 2 feet of product was identified in wells P-81 and P-105.

The Rand Sand

An aquifer performance test was conducted during May 1990 in the vicinity of the Rand Avenue area in order to investigate the hydraulic properties of the upper sand interval (Rand Sand) under investigation. In addition, three geotechnical soil borings were completed in 1991, and soil samples were obtained and analyzed to determine hydraulic properties of this interval. The soil samples collected were obtained from just above, just below, and within the Rand Sand interval under investigation. A report summarizing the results of this investigation is included in Appendix U.

The uppermost saturated sand interval under investigation is known as the Rand Sand. This sand interval is encountered approximately 20 feet below surface and is separated from the EPA Sand by a clay layer that varies in thickness from 3 to 11.5 feet. The stratigraphy of the Rand Sand is illustrated by the geologic cross-sections shown in Figures 14-17.

An isopach map illustrating the thickness of the Rand Sand, based on the lithologic data collected and summarized in Table 3, is shown in Figure 29. The extent of the Rand Sand is determined by the location of the zero contour line.

The potentiometric surface of the Rand Sand, corrected for product thickness and based on the data collected during the Third Quarter of 1990, is shown in Figure 30. The groundwater flow direction, based on the data collected and summarized in Table 3, is to the northeast. Groundwater flow in the Rand Sand mimics the direction of groundwater flow of the Main Sand. Therefore, groundwater flow in the vicinity of Hartford is to the northeast, influenced by the cone-of-depression maintained by Shell at the Main Plant property and the cone-of-depression maintained at the Rand Avenue site.

Hydrocarbon thickness data collected from wells screened across the Rand Sand are illustrated in Figures 31-33. Tables 3, 4, and 5 summarize the data collected. The thickness of the hydrocarbon layer measured on March 22, 1990, is illustrated by Figure 31; as measured on May 31, 1990, is illustrated by Figure 32; and, as measured during third quarter 1990, is illustrated by Figure 33.

An aquifer performance test was completed by ES at the Rand Avenue site during May 1990. The aquifer test data and a report summarizing the test results is included as Appendix S. A letter issued by ES during re-evaluation of the aquifer test results is also included in Appendix S.

The primary objective of the aquifer performance test was to determine specific hydrogeologic parameters appropriate for designing a hydrocarbon recovery system at the Rand Avenue release site. Another, secondary objective of the aquifer test, was to investigate the potential for hydraulic connection between the Rand and EPA Sands. The primary objective of the aquifer test was achieved with the test as designed. However, the aquifer test, as designed, did not evaluate the potential for hydraulic communication between the Rand and EPA Sands. However, based on a statistical analysis of the barometric pressure data and water level fluctuations observed in Well SP-14 during the aquifer testing, the potential for hydraulic connection between the EPA and Rand Aquifers can be investigated (Appendix S). The preponderance of evidence summarized in the aquifer performance re-evaluation letter indicates that the EPA and the Rand Sands do not appear to be in hydraulic communication.

Hydraulic properties of the Rand Sand interval were obtained during aquifer testing. The average value of hydraulic conductivity (K) for this interval, based on the aquifer pump test, was determined to be 92.6 gpd/ft^2 (5.2 x 10^{-3} cm/sec). In addition, the average values of transmissivity (T) and storivity (S) were determined to be 280 gpd/ft and 0.0033, respectively. The value of storivity indicates semi-confined aquifer conditions (Appendix S).

ES conducted three geotechnical borings at the Rand Avenue release site on October 22, 1991. The objective of this investigation was to determine the mechanical properties of the Rand Sand interval. All collected samples were analyzed for moisture content, unit weight, specific gravity, and grain-size distribution. In addition, one sample each from the base of the Rand Sand and the clay unit between the Rand and EPA sands were tested for vertical hydraulic conductivity (K_u). Geotechnical analyses were provided by John Mathes and Associates of Columbia, Illinois. The report detailing the results of this testing is located in Appendix U.

Table 6 lists the results from the laboratory analyses of soil samples. The natural moisture content of samples collected were found to contribute 29.1 percent to 54.4 percent of the total sample weight. The dry unit weight of soils resulted in densities ranging from 65.3 pounds per cubic foot (pcf) to 85.5 pcf. When these densities are normalized to an equivalent volume by the density of water, the resultant ratio is a property known as a specific gravity. Specific gravities of the collected samples ranged from 2.60 grams per cubic centimeter (g/cm^3) to 2.69 g/cm^3. Each value is a weighted average of the sample constituents: clay (2.60 g/cm^3), silt and sand (2.65 g/cm^3), and traces of heavy minerals (>2.8 g/cm^3).

Porosity of the clay samples collected from each boring was calculated. Porosity is the ratio of the total volume of voids to the total volume of the sample. Porosity values ranging from 47.3 percent to 57.3 percent were found in five separate silty clay samples. These values are typical for sub-compacted clays. However, these values in no way indicate that these clays can transmit fluids at a rapid rate. This is because the effective porosity, or amount of interconnected pore spaces, is low. As an example, the sample S-4-3, collected 26.0 feet to 26.5 feet below grade at B-1, is the clay beneath the Rand Sand. Laboratory testing indicated a vertical permeability of 2.9 x 10^{-8} centimeters per second (cm/sec). This would indicate the vertical percolation of fluids from the Rand Sand to the EPA Sand occurs at a very slow rate. Calculations of seepage velocity through the clay layer between the Rand and EPA Sands illustrate that water would take over 14 years to vertically migrate through this clay layer (Appendix U).

In order to describe the nature of the soils, a grain-size distribution analysis was conducted on each of the 11 submitted samples. This analysis is useful to empirically describe the soils based on the actual percentages of sand, silt, and clay in the sample. Table 7 lists each soil sample with its compositional percentages and lithologic description. For components larger than 0.074 millimeters (mm) in diameter (sand), the U.S. Standard Sieve Analysis was performed. For grains with diameters less than 0.074 mm (silt) and 0.004 mm (clay), a hydrometer was used for determining the particle-size distribution.

As summarized in Table 7, the S-1 samples collected above the Rand Sand are chiefly silts (70 percent) and clay (26 percent). S-2 samples collected from within the Rand Sand indicate a mixture of sand (42.67 percent), silt (45.67 percent), and a trace of clay (11.66 percent). These results may, however, be skewed by the apparent thinning of the Rand Sand at B-2. Only one sample was collected at the base of the Rand Sand (S-3 from Boring #1). This sample is a good example of how the Rand Sand grades into a silt and, eventually, a clay. This is further demonstrated by three samples collected at the lithologic contact of the Rand Sand and the underlying clay. These samples showed mixtures of 6 percent sand, 60.33 percent silt, and 33.66 percent clay. One grain-size distribution analysis was completed exclusively on the lower clay unit at location B-1. At 26.5 feet to 27.0 feet below grade, the composition was 1 percent sand, 22 percent silt, and 77 percent clay. The particle size analysis curves appear in Attachment A of the letter report located in Appendix U.

In general, based on the data collected during this investigation, the Rand Sand occurs at depths 18 feet to 25 feet below grade, and ranges in thickness from 3 feet at boring B-2 to 7 feet at boring B-1. The strata overlying the Rand Sand is a gray-brown silty clay that is composed of 4 percent sand, 70 percent silt, and 26 percent clay. The Rand Sand is a sand (43 percent)/silt (45 percent) mixture with minor amounts of clay. It is described as a gray-brown silty sand with a formation density characterized as loose by Standard Penetration Tests conducted during boring activities. The vertical hydraulic conductivity at the base of the Rand Sand is 2.0 x 10^{-5} cm/sec, which is typical for sand, silt, and clay mixtures.

Regional Groundwater Map

In a joint effort to compile regional groundwater maps of the Hartford, Illinois, area, groundwater elevation data were collected from wells owned by Amoco, Clark, and Shell during the week of July 16, 1990. A portion of the data collected is summarized in Table 3 of this report.

The groundwater elevation data collected were compiled by Geraghty & Miller, consultants to Amoco. Two groundwater elevation maps were issued based on this data. One map illustrates groundwater data collected from monitoring wells screened in the Main and EPA Aquifers (Figure 34). The other map illustrates groundwater elevation data collected from monitoring wells screened across intervals stratigraphically above the Main Aquifer (Figure 35).

Inspection of Figure 34 reveals the fact that the groundwater elevation contours appear to exhibit a "mounding" effect in two separate areas of the map. This effect occurs at the northeastern corner of Hartford and at the western end of the Clark facility. A traverse from southwest to northeast across Figure 34 will serve to illustrate the mounding effect shown at the northeast corner of Hartford. Beginning at the western edge of Hartford, the groundwater gradient slopes to the northeast. Near the northeast corner of Hartford one crosses the 401-foot contour line, then the 400-foot contour line. Continuing northeastward one encounters, in succession, the 401-foot contour line, the 402, and the 403-foot lines before once again crossing contour lines of descending groundwater elevation values, i.e., the 403, 402, 401, and

400-foot contour lines. The groundwater elevation contours described illustrate the mounding effect near the northeast corner of Hartford. From a point near the position of the Rand Avenue release site, the groundwater gradient continues its downward slope toward the northeast corner of the map.

The data used to illustrate the groundwater gradient depicted on Figure 34, in the area of the apparent mounding near the Rand Avenue release site, were based on measurements of the groundwater elevations in the following wells:

- Hartford wells - B-19, B-32, B-33, and RW-2;
- EPA well - EPA-7; and
- Shell wells - P-76, P-107, SP-12, SP-13, SP-14, and SP-18.

With the exception of well RW-2, each of the wells listed above are either screened in the EPA Sand; in both the EPA Sand and the underlying Main Sand; or in the Main, EPA, and Rand Sand intervals. Well RW-2 is screened only across the Main Sand interval.

Thus, the gauging data obtained from these wells reflect the fact that water has entered each well bore from several, hydraulically separated, saturated intervals. Therefore, the data collected do not accurately reflect the groundwater elevation of the Main Aquifer. Accurate groundwater elevation maps are based on measurements obtained from wells screened across hydraulically equivalent intervals. The mounding effects noted at the northeast corner of Hartford and the western edge of the Clark facility are caused by groundwater elevation data obtained from wells screened across several, hydraulically separate intervals. In effect, the groundwater elevations obtained from each well represent the sum (or "composite") of separate hydraulic head measurements.

Use of well data from wells screened exclusively in the Main Aquifer will produce a groundwater elevation contour map with a regular and consistent northeast groundwater gradient, as shown in Figure 22.

Figure 35 illustrates groundwater elevation data collected from monitoring wells screened across saturated sand intervals above the Main Sand. In the vicinity of Rand Avenue, this interval has been designated as the Rand Sand. Based on data concerning well screen placement depth, at least two more shallow, saturated intervals are present beneath both the Amoco and Clark facilities. These shallow sand intervals screened in the monitoring wells shown in Figure 34 are both lithologically and hydraulically separated. It is, therefore, not technically accurate to construct a groundwater elevation map illustrated based on this data. The groundwater data as presented in Figure 35 is, therefore, misleading because the measurements represent "composite" effects from each separate interval screened. An accurate representation of the groundwater gradient within the Rand Sand, for example, is illustrated by Figure 30.

AREAL EXTENT OF AQUIFERS, GROUNDWATER ELEVATIONS, AND HYDROCARBON COMPLAINTS

AREAL EXTENT

A major factor controlling the migration of product beneath Hartford is the areal extent of the aquifers and the location of the less permeable clay lens (barriers) found separating the aquifers. Figure 36 is a map illustrating the extent of the Main, EPA, and Rand Aquifers beneath the Village of Hartford. The Main Sand underlies the entire area shown in the map. The cross-hatched area represents the mapped extent of the clay lens that separates the EPA and the Main Sands. Therefore, this cross-hatched area represents the location of the EPA Sand. The map also illustrates the extent of the Rand Sand, the saturated sand interval stratigraphically above the EPA and Main Aquifers.

Figure 37 is a location map showing the locations of the homes in the village of Hartford that have had documented odor complaints during the time period 1981 through 1990. Figure 38 is a location map which identifies homes in the village of Hartford that have had documented fires during the time period 1981 through 1990.

Figure 39 depicts the documented fires that have occurred in the village of Hartford since the 1989 Shell pipeline release near Rand Avenue. One home fire occurred in the village of Hartford at a location within the mapped areal extent of the Rand Sand. This fire occurred on May 20, 1990, in the home of Mr. Jeff Bartlett at 101 East Birch Street. Three other fires also occurred during that week, at distances of 300 feet to 1,200 feet beyond the margin of the Rand Aquifer. Five months later, during October 1990, a soil gas survey was conducted in this area of Hartford to investigate the source of home fires. The results of this survey indicated that hydrocarbon vapors associated with the Rand Avenue release had not migrated to the southwest in the direction of Hartford. This evidence indicates that the home fires that occurred during March and May 1990 in the village of Hartford were not the result of the Shell Rand Avenue pipeline release.

On November 7 and 8, 1989, a number of wells gauged in the vicinity of Forest and Birch Streets in Hartford contained measurable thickness of hydrocarbons. The results of this gauging episode are found in Appendix V. Well B-19 in the 100 block of East Birch Street, near the property of Mr. Jeff Bartlett, contained 0.25 feet of separate-phase hydrocarbon. During this same gauging event, 0.6 feet of separate-phase hydrocarbons were measured in well B-7, located on Forest Street. This gauging event established that a significant amount of hydrocarbons were present in the subsurface beneath Hartford in the vicinity of Forest Street and Birch Street at least one month before the occurrence of the release from the Shell pipeline at Rand Avenue.

Groundwater Elevations and Hydrocarbon Complaints

It was first noted by Amoco in 1973 that a direct relationship exists between the number of hydrocarbon odor complaints received from Hartford residents and a rise in the water table. When the water table rises, the number of hydrocarbon odor complaint increases. This relationship is explained in a letter attached to the 1990 IEPA report located in Appendix A. Mr. F. K. Webb (Amoco) documented this relationship in a letter dated March 13, 1973, addressed to the State Fire Marshall, Mr. B. F. Sadowski. This letter states in part, "all complaints coming to our attention have followed heavy rains and a rise in river level, which would tend to flood sewers and raise the water table, forcing gas from sewers and underground gas and hydrocarbons to the surface."

The report issued by Mathes in 1978 (Appendix F) states "experience has indicated that explosive mixtures are generally present only for a relatively short period of time in a particular area and that gas odor reports usually occur after periods of heavy rain or when the levels of the Mississippi River are rising." The Mathes report also summarized the relationship between water level elevations and seasonal rainfall patterns. The elevation of groundwater beneath Hartford decreases in late spring when groundwater withdrawal exceeds rainfall recharge. The Main Aquifer starts to recover in the early winter months and groundwater levels tend to rise during the wet spring months. Historically, groundwater level elevations are highest in May and lowest in December.

In support of the above relationship between rising water table elevations and the occurrence of hydrocarbon vapors in the subsurface, all but two of the reported house fires in the village of Hartford listed in Table 2 occurred during the spring months of March, April, and May. The remaining two fires occurred during the early summer months of June and July.

Figure VI of Appendix F is a hydrograph prepared by Mathes in 1978. This hydrograph illustrates the correlation of fluctuations of groundwater and the number of hydrocarbon odor complaints documented by Hartford residents. The following conclusions drawn by Mathes are based on the data illustrated by this figure:

- complaints of gas odors generally occurred when the groundwater level began to rise;
- occasional complaints were received when the groundwater level was already high but was falling;
- some complaints would occur immediately after heavy rainfall;
- the upward movement of the groundwater level appears to be closely related to reports of gas odors (Mathes, 1978).

In addition, the following documentation supports the conclusion that rising water levels primarily noted during the spring months of the year increase the potential for hydrocarbon vapor emissions and potential house fires in the village of Hartford:

- Four house fires occurred during the second week of April after a 5-inch rain (Appendix E, Volume I of the report titled "Geohydrological Site Assessment" issued by Shell Oil Company and authored by Mr. William Shepherd).
- A house fire occurred at the home of Mr. Doug Neal on May 16, 1990, after "extremely heavy rains" (Appendix D). Within the next four days, three additional fires occurred in homes located in Hartford (Table 2).

Figures 40 and 41 are hydrographs that have been compiled from gauging data provided by the Illinois State Water Survey (Appendix W). The well gauged is located approximately 0.75 miles northeast of Hartford and represents regional groundwater seasonal fluctuations. This groundwater pumping well is owned and operated by Marathon Oil Company, and is completed to a depth of 107 feet. Figure 40 illustrates the number of documented hydrocarbon odor complaints and measured groundwater elevations for a period extending from 1961 to 1990. It can be seen that the majority of hydrocarbon odor complaints occur during periods of high groundwater elevations. Figure 41 is a hydrograph that illustrates the number of documented house fires. In every case documented, house fires occurred during periods of increasing or peak groundwater elevations.

Of great significance is the fact that no house fires were reported during a period of severe drought that began in 1987 and continued until the end of 1989. In addition, only one hydrocarbon odor complaint was documented during 1987, and only two odor complaints were documented during 1988. The number of house fires and documented odor complaints once again increased with the advent of normal rainfall and subsequent aquifer recharge that has occurred since February 1990 (Figure 40 and 41).

The documented pattern of rising groundwater elevations and increased house fires and hydrocarbon odor complaints described above strongly suggests that fluctuation of groundwater elevations is a primary factor controlling hydrocarbon vapor emanation from the subsurface beneath Hartford. Considering this strong casual relationship, the increased number of documented house fires in the village of Hartford during 1990 is the result of aquifer rebound after a severe two-year drought and not the result of the Shell pipeline release.

PRODUCT TYPES VS. LOCATION

Studies to determine the type of product released in the Hartford area were performed by Mathes in 1978 (Appendix F) and by the Illinois Environmental Protection Agency (IEPA) in 1990 (Appendix A). These reports indicate that fuel oil and leaded and unleaded gasolines have been released from various product pipelines present in the subsurface in and around the village of Hartford.

The 1978 Mathes report suggests that the presence of methane in the subsurface around Hartford may be a major cause of the gas odor and house fire complaints associated with many homes in Hartford. The source of this methane has been investigated, but is not established. Two landfills are present south and east of Hartford, but are located too far away to be considered a methane source. Natural deposits of coal and peat sometimes are sources of methane in the subsurface, but such deposits have not been identified in the vicinity of Hartford. Sanitary sewers sometimes, but rarely, produce methane, so this source of methane production was also discounted. Methane may also be generated by leading natural gas pipelines, but no such leak has been reported. Finally, natural gas is sometimes produced from bedrock formations, but no natural gas source is known to exist in the bedrock beneath Hartford.

The IEPA report (Appendix A) summarized the results of laboratory analyses of two sets of product samples obtained from Clark monitoring and recovery wells in Hartford, from two EPA wells, from three Shell wells (wells SP-3, SP-26, and P-105), and from the Arco/Sinclair pipeline. The results of the analysis of these two groups of samples are presented in Attachment 13 of Appendix A. Based on the analytical results reported, the following conclusions were reached by the IEPA:

- product sampled from the two Clark recovery wells and the Clark monitoring well B-16 is leaded gasoline containing tetraethyl lead (TEL);
- product sampled from the Shell well P-105 is leaded gasoline containing TEL;
- product sampled from the Shell well SP-26 is unleaded gasoline;
- product sampled from the Arco/Sinclair pipeline is unleaded gasoline;
- the gasoline present in the Clark wells were manufactured using the sulfuric acid alkylation process.

The affidavit (Appendix X) given by Mr. C. R. Woodford, manager of dispatching at WRMC, on February 10, 1981, is important, as it relates to manufacturing processes used by Shell at WRMC from May 1977 until late 1978. In his affidavit, Mr. Woodford discussed the process used by Shell to manufacture both leaded and unleaded gasoline. During the stated interval, Shell added lead to gasolines in the form of tetramethyl lead (TML). The leaded gasoline that occurs in the wells cited above is tetraethyl lead (TEL). Other gasolines produced by Shell contain an alkylate produced only by a sulfuric acid alkylation process. Based on analysis of the product samples from the wells cited above, the hydrocarbon found beneath Hartford was derived from the hydrofluoric acid alkylation process, which is the process used by Clark Oil Company.

Table 1 of Attachment 13 in Appendix A lists the percent, by liquid volume, of paraffins, olefins, napthanes, and aromatics found in the product samples collected from the Clark monitoring and recovery wells, from the Shell wells samples (wells SP-26 and P-105), and from Arco/Sinclair pipeline. The laboratory results for the samples obtained from well P-105 show that the composition of the product correlates, to some extent, with the composition of the product sampled from the Clark recovery wells and the Arco/Sinclair pipeline. However, the analytical laboratory results corresponding to the sample obtained from well P-105 do not correlate with the laboratory composition of the sampled product obtained from the other Shell wells (SP-26). Therefore, no correlation as to product composition exists between the product sampled in wells SP-26 and P-105. However, such a correlation exists, at least partially, between the product sampled from the Shell well P-105 and the product obtained from both the Clark wells and the Arco/Sinclair pipeline. Furthermore, the lead additive found in well P-105 was TEL, which is an additive used by Clark and not by Shell. Therefore, consideration of these facts and observations lead to the conclusion that the product found in well P-105 may be a combination of product types found in the Clark wells sampled and the product found in the Arco/Sinclair pipeline.

In his affidavit, Mr. Woodford also stated that from 1973 through 1978, Shell used Freon II as a tracer in their regular leaded gasoline. However, Freon II was not reported in the laboratory analyses of the product samples from the wells cited above.

To summarize, the lead additive used by Shell during the period in question was TML. The lead additive found in the gasoline samples from the wells completed in and near the town of Hartford, Illinois, is TEL. These two lead additives are different and distinct. Based on the laboratory results, the evidence is that the gasoline product present in the Hartford area wells sampled is not Shell gasoline. The lead additive used by Clark Oil is TEL, and the lead additive found in the Arco/Sinclair pipeline is TEL. Thus, the gasoline found in the Hartford wells may have come from either Clark Oil or from the Arco/Sinclair pipeline.

CONCLUSIONS

Engineering-Science, Inc., has completed a study of the history and nature of hydrocarbon releases in the Village of Hartford, Illinois. The purposes of this study were to: (1) provide a historical chronology of the subsurface hydrocarbon problem in Hartford, and (2) to asses what role, if any, the December 16, 1989, Shell unleaded gasoline release north of Rand Avenue plays with respect to the problem of hydrocarbon-related fires and vapor complaints reported from Hartford village residents.

Hydrocarbon vapor complaints from Hartford residents dating from 1966 are documented. The IEPA investigated the problem in 1978. This investigation was prompted by a series of house fires that occurred in Hartford during March 1978. The source of the released hydrocarbons causing complaints was traced to releases from underground pipelines owned by Clark Oil Company. As a result, Clark voluntarily agreed to install product recovery wells in an attempt at hydrocarbon remediation.

Mathes completed a hydrogeological investigation of the Hartford area in 1978. The direction of groundwater flow in the vicinity of Hartford was determined to be in a northeasterly direction. The groundwater flow direction is controlled by the pronounced cones-of-depression maintained since 1951 by the Amoco and Shell facilities. Geologically, a thick, continuous clay layer that increases in thickness to the east beneath Hartford potentially acts as a clay barrier to hydrocarbon movement. The clay barrier potentially traps hydrocarbons, allows hydrocarbon accumulation, and may cause the observed distribution of vapor and house fire complaints (Mathes, 1978).

Product sampled from wells installed during the initial investigation by Mathes contained the organic lead antiknock additive tetraethyl lead (TEL). The lead additive used by Shell is tetramethyl lead (TML). However, the lead additive used by Clark and Arco (Sinclair) is tetraethyl lead (TEL). Therefore, the gasoline product found in the Hartford area wells in 1978 may have come from pipelines owned by Clark or Arco/Sinclair, but not Shell-owned pipelines.

New investigations into the lithology of the subsurface and groundwater contamination conditions beneath Hartford were launched after the Shell pipeline release along Rand Avenue during December 1989. Additional investigations were also prompted by numerous hydrocarbon vapor odor and fire complaints received during the spring of 1990. The results of these investigations are summarized below:

- Product accumulation at the Rand Avenue release site is confined to the uppermost aquifer: the Rand Sand.
- The direction of groundwater flow in the Rand Sand in the vicinity of the Rand Avenue release site is to the northeast, away from the village of Hartford.
- Separate-phase product was detected beneath the village of Hartford in well B-19, apparently screened below the Rand Sand, during November 1989. Product was, therefore, detected beneath Hartford even before the Shell pipeline release.
- Soil-gas survey results suggest that vapor migration from the Rand Avenue release site is impeded to the south, west, and northwest by clays and silty clays. These low permeability clays provide a barrier to vapor migration.
- Elevated soil-gas vapor concentrations near the intersection of North Olive and Rand Avenue indicate the location of the vapor plume associated with the documented 1978 fuel oil release from a Clark-owned pipeline.

The IEPA has determined that the large accumulation of hydrocarbons beneath Hartford was apparently the result of Clark pipeline releases. The IEPA estimates that between 900,000 and 3,800,000 gallons of leaded gasoline remain in this plume, although Clark has reported recovering approximately 1,160,000 gallons of hydrocarbons. The IEPA determined that the location of the product plume, trapped against a low permeability clay layer, and the groundwater flow direction toward the northeast in the vicinity of Hartford, make it highly improbable that this plume originated from the Amoco facility or from the Shell pipeline release at Rand Avenue. The surge in number of vapor complaints and fires that occurred during 1990 were caused by water level upward movement in the aquifer as it rebounded after a severe, two-year drought.

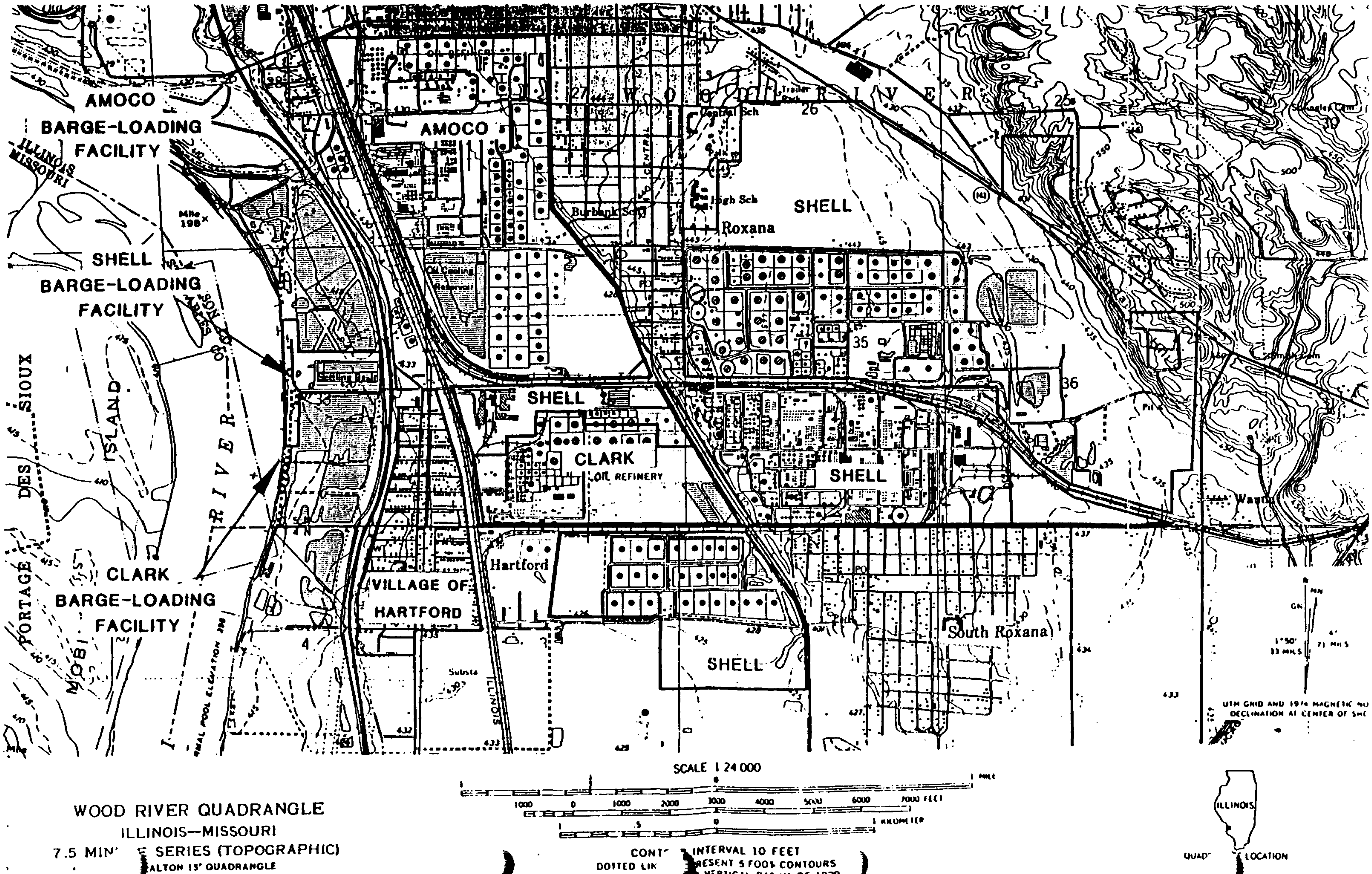
The recovery system operated at Rand Avenue by Shell was upgraded in April 1991. Three groundwater recovery wells currently operate to maintain a groundwater cone-of-depression to control product movement. In addition, the results of aquifer testing and geotechnical soil sampling indicate that there is hydraulic separation between the aquifers that exist beneath the Rand Avenue release site. The upper aquifer, the Rand Sand, is separated from the lower aquifer, the EPA Sand, by a clay layer averaging over 5 feet thick. Product is confined to the upper aquifer, and the intervening clay layer retards vertical groundwater movement. Calculations indicate that groundwater percolation through this clay would take approximately 14 years.

Hydrocarbons found beneath Hartford do not chemically compare to the composition of the product released from the Shell pipeline at Rand Avenue. Product beneath Hartford was sampled and analyzed, and was determined to be leaded regular gasoline with tetraethyl lead (TEL) as the primary alkyl lead additive. The Shell release at Rand Avenue was unleaded regular gasoline. The hydrocarbon found beneath Hartford contains an isomer ratio that is found in hydrofluoric acid refining processes. This refining process is used by Clark. Shell uses the sulfuric acid refining process which contain isomer ratios that do not match the hydrocarbon types found beneath Hartford.

Based on the facts presented, it can be concluded that the migration of hydrocarbons to the south, in the direction of Hartford, from the Rand Avenue release site would be geologically impeded and hydraulically improbable; this migration has not occurred.

FIGURE 1

SITE LOCATION MAP



WOOD RIVER QUADRANGLE
ILLINOIS—MISSOURI
7.5 MINUTE SERIES (TOPOGRAPHIC)

Figure 2

Hartford Map

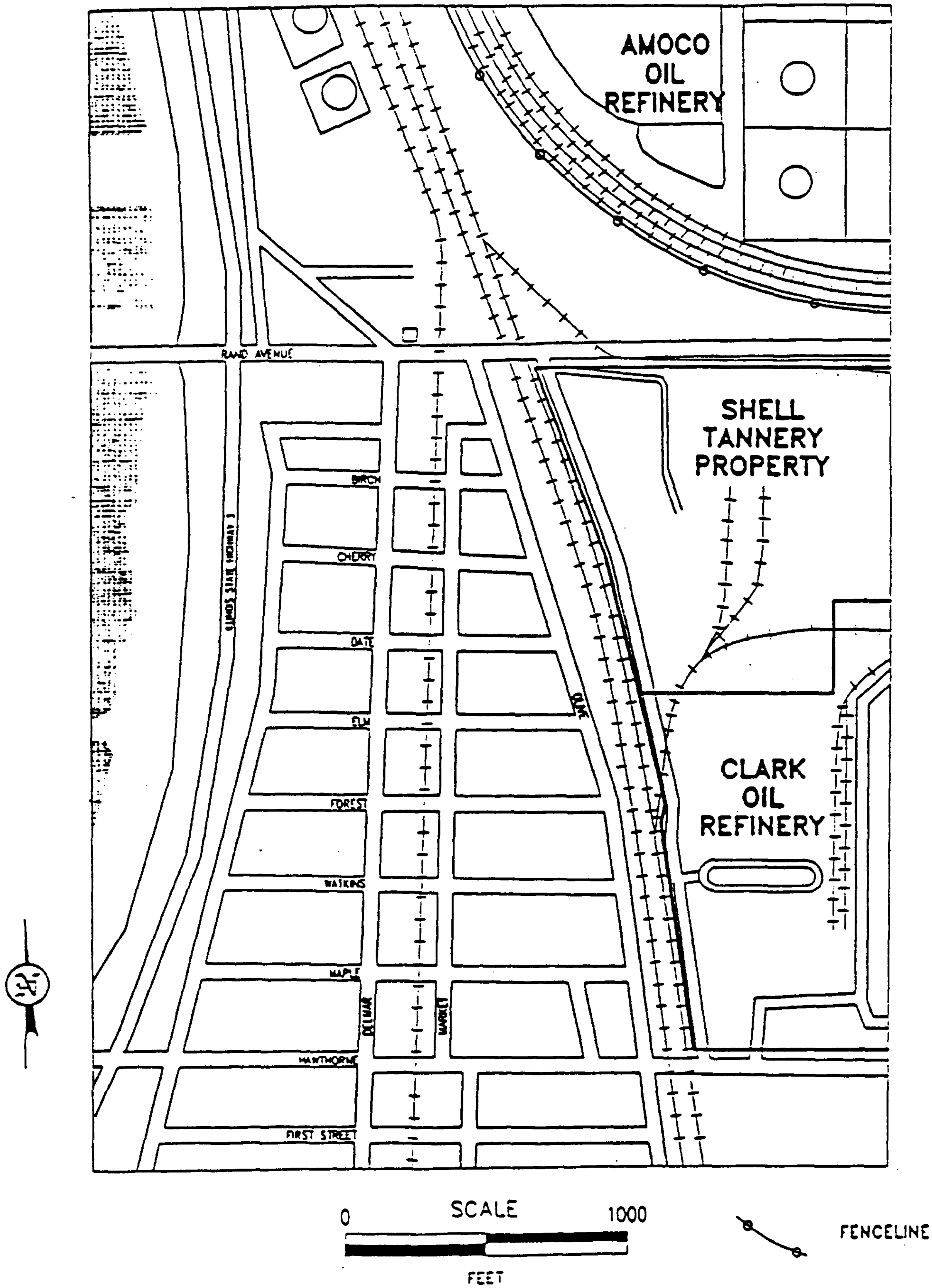
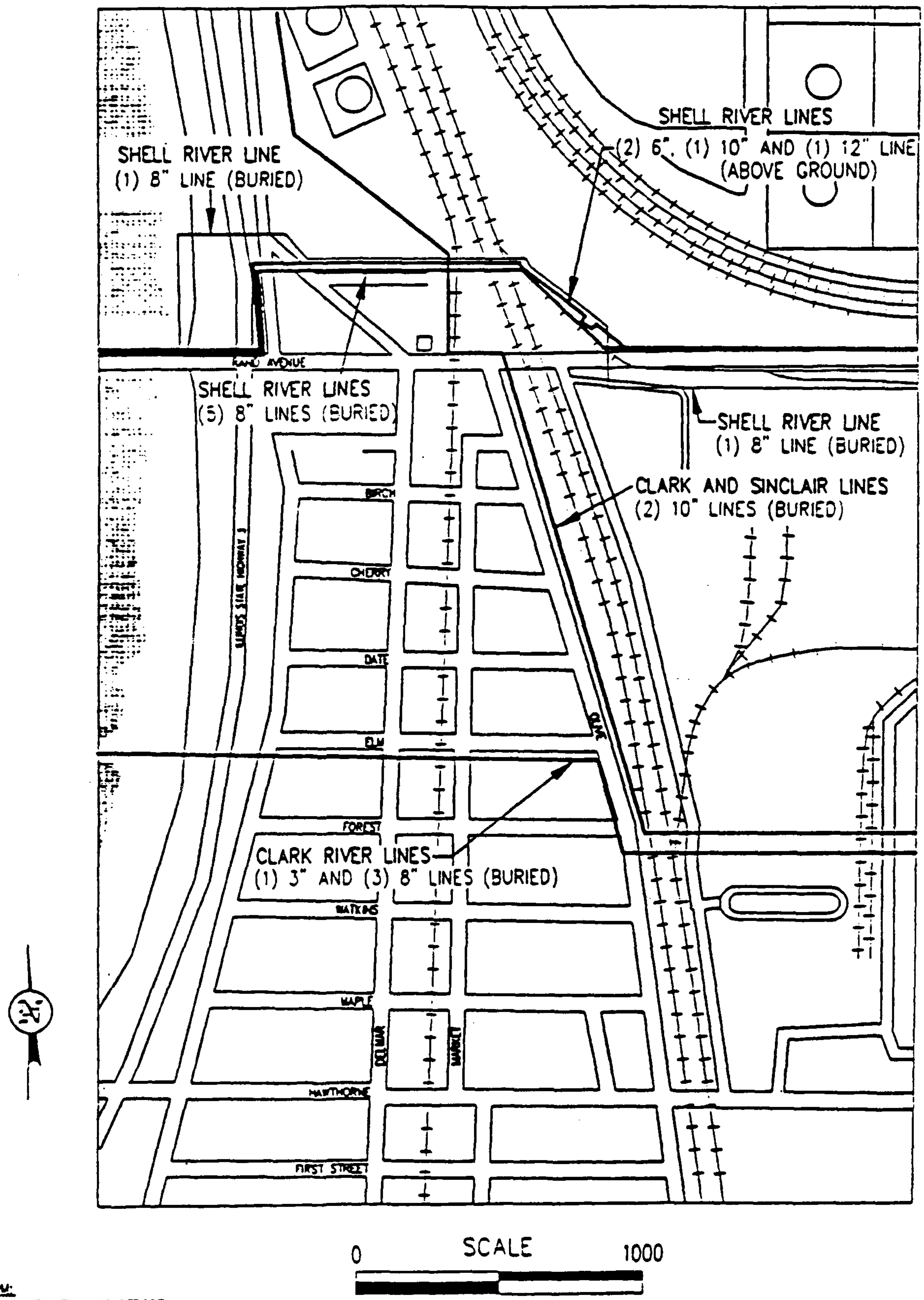


Figure 3

Product Lines Near Hartford

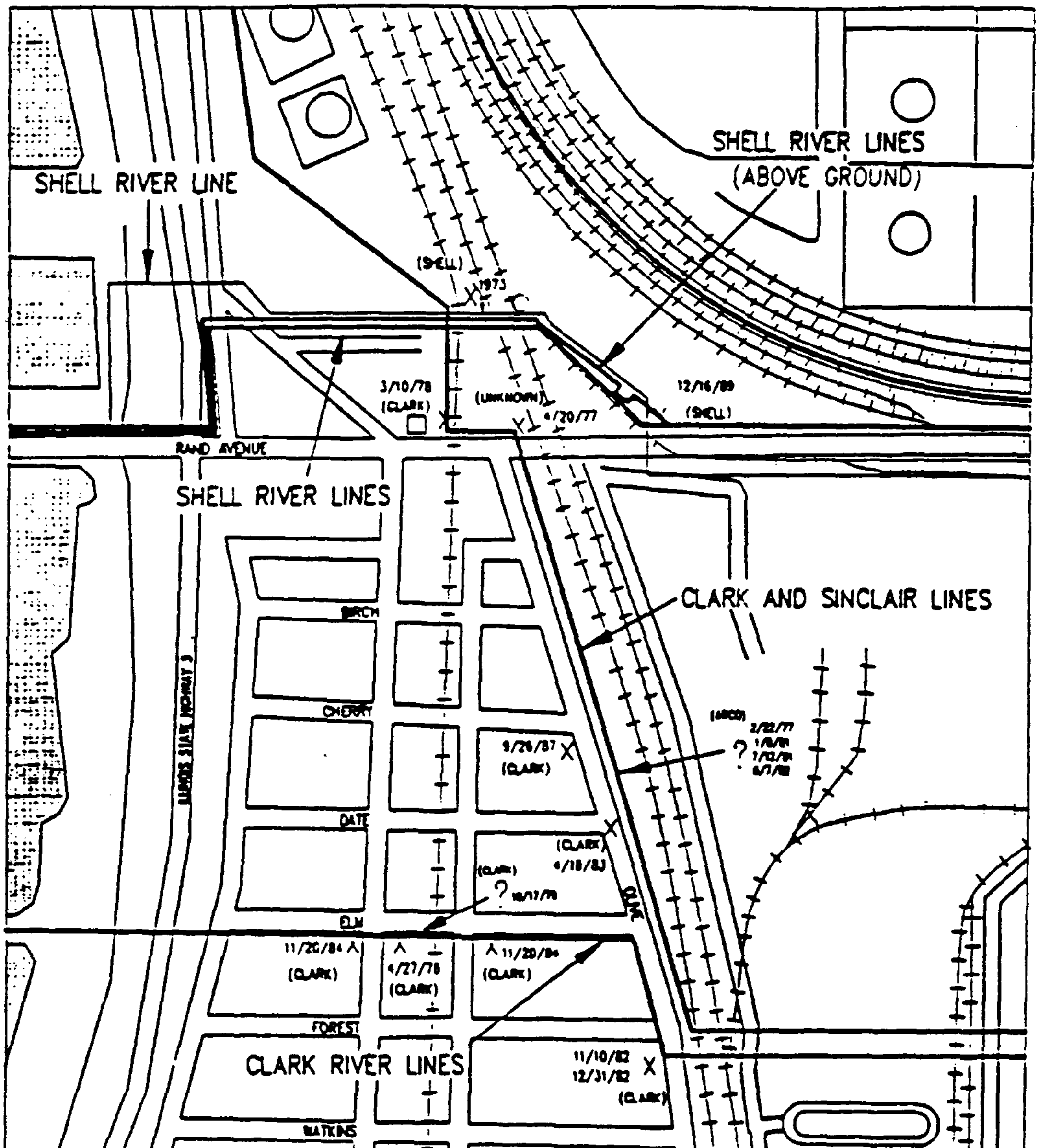


FROM:
IEPA NOVEMBER 1990 REPORT,
1968 SHELL OIL PIPELINE MAP SK-5385,
AND DRAWINGS SK-8202-2, E-14288-1, AND E-14289-2

FIG03

Figure 4

Product Release Map



HYDROCARBON RELEASES IN HARTFORD

DATE	OWNER/OPERATOR	PRODUCT	VOLUME
3/23/73	SHELL	BENZENE	NOT DETERMINED
2/22/77	ARCO	GASOLINE	NOT DETERMINED
4/20/77	NOT DETERMINED	NOT DETERMINED	NOT DETERMINED
3/10/78	CLARK	FUEL OIL	NOT DETERMINED
4/27/78	CLARK	GASOLINE	NOT DETERMINED
10/17/78	CLARK	GASOLINE	NOT DETERMINED
1/8/81	ARCO	GASOLINE	5 BBL
7/12/81	ARCO	GASOLINE	24 BBL
6/7/82	ARCO	FUEL OIL	9 BBL
11/10/82	CLARK	DIESEL OIL	NOT DETERMINED
12/31/82	CLARK	NOT DETERMINED	NOT DETERMINED
4/18/83	CLARK	NOT DETERMINED	NOT DETERMINED
11/20/84	CLARK	LIGHT CYCLE OIL	NOT DETERMINED
9/26/87	CLARK	NOT DETERMINED	NOT DETERMINED
12/16/89	SHELL	UNLEADED GASOLINE	NOT DETERMINED

SCALE

0 — 1000

FEET

X = DOCUMENTED RELEASE AND LOCATION

? = DOCUMENTED RELEASE AT UNDETERMINED LOCATION

FROM:
IEPA NOVEMBER 1990 REPORT,
1968 SHELL OIL PIPELINE MAP SK-5385,
AND DRAWINGS SK-8202-2, E-14288-1, AND E-14289-2

Figure 5
Homes with Odor Complaints (1981 - 1990)

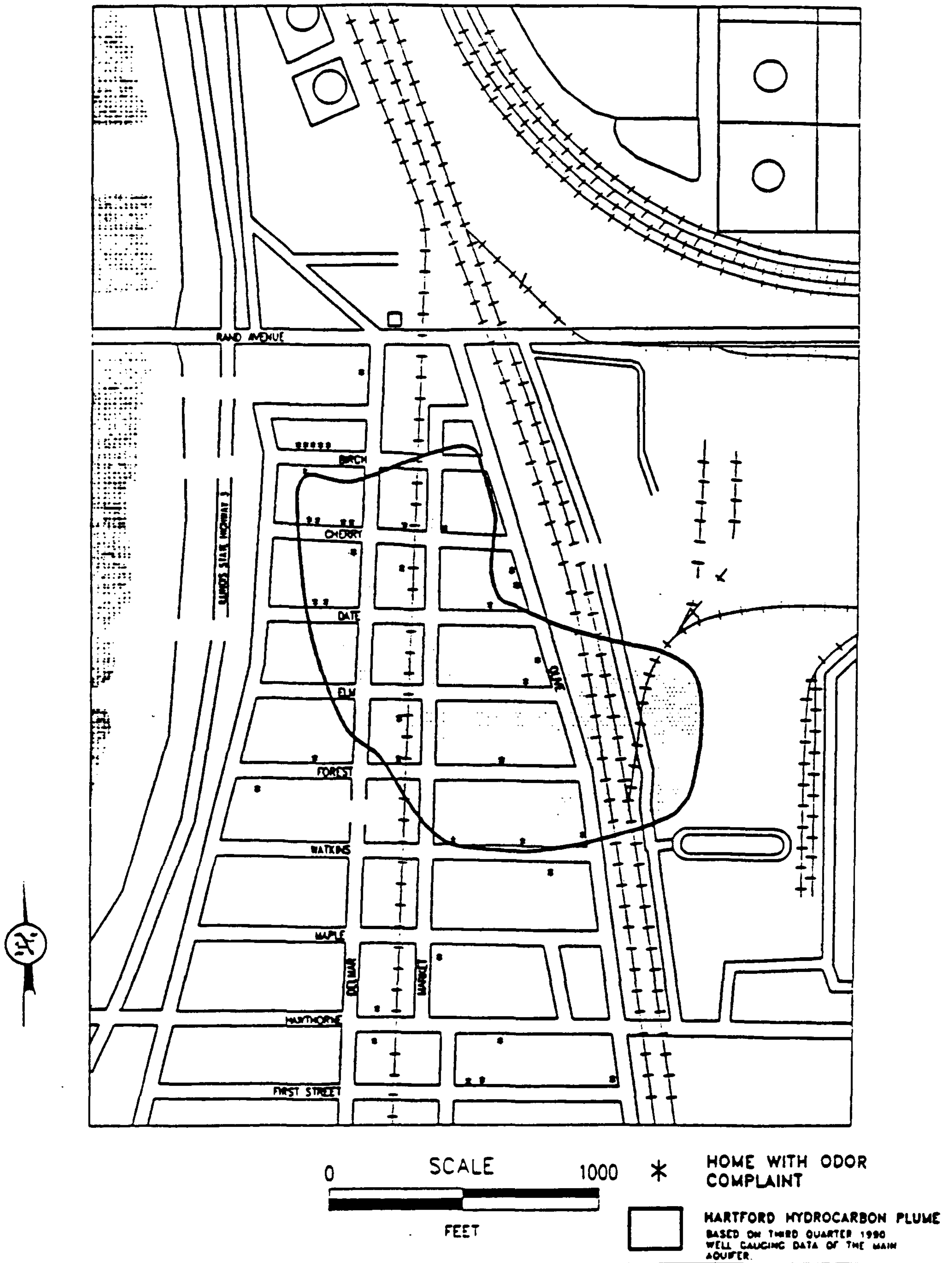


FIG05-06

Figure 6

Homes with Fires (1970 - 1990)

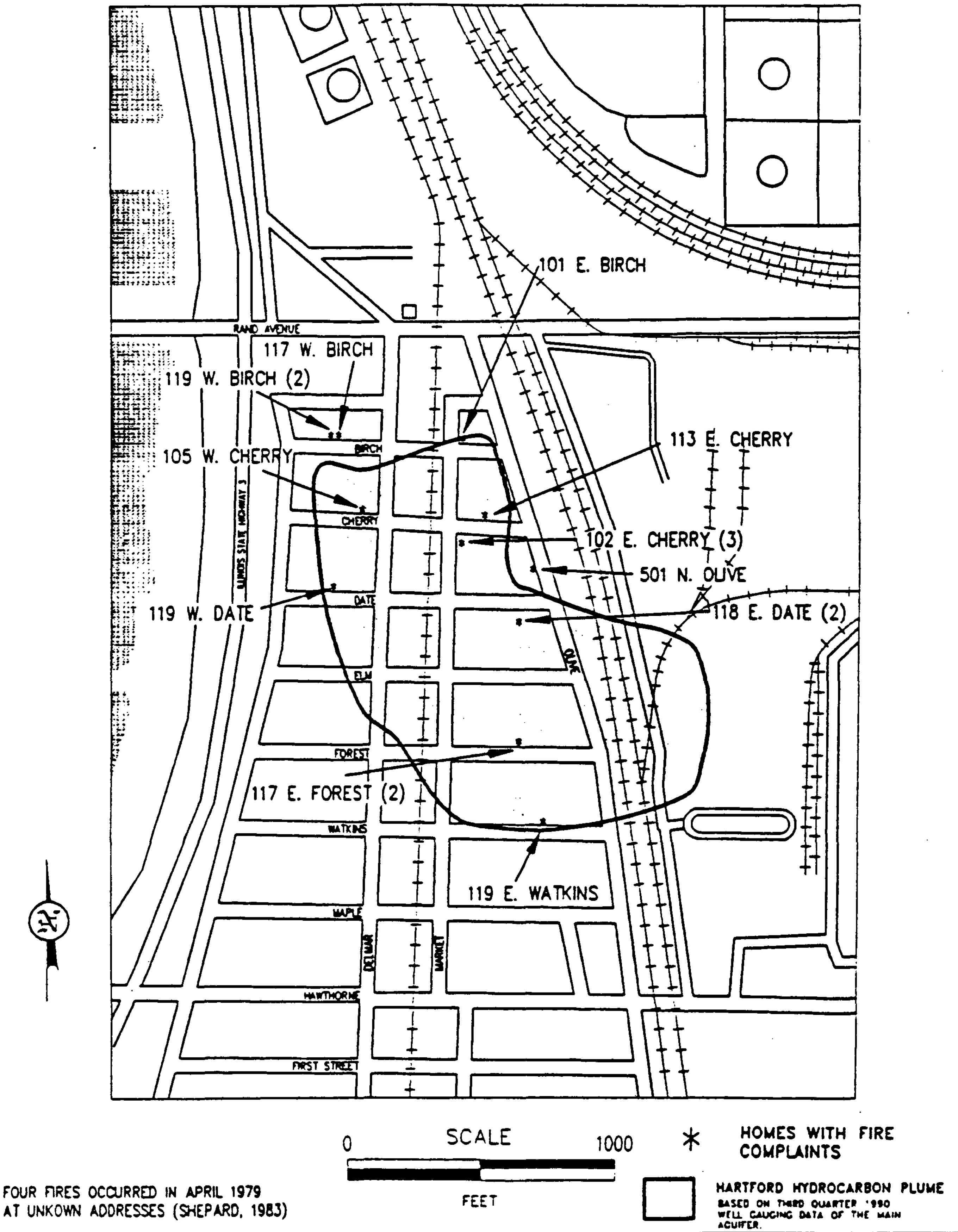


Figure 7

Monitor Well Location Map

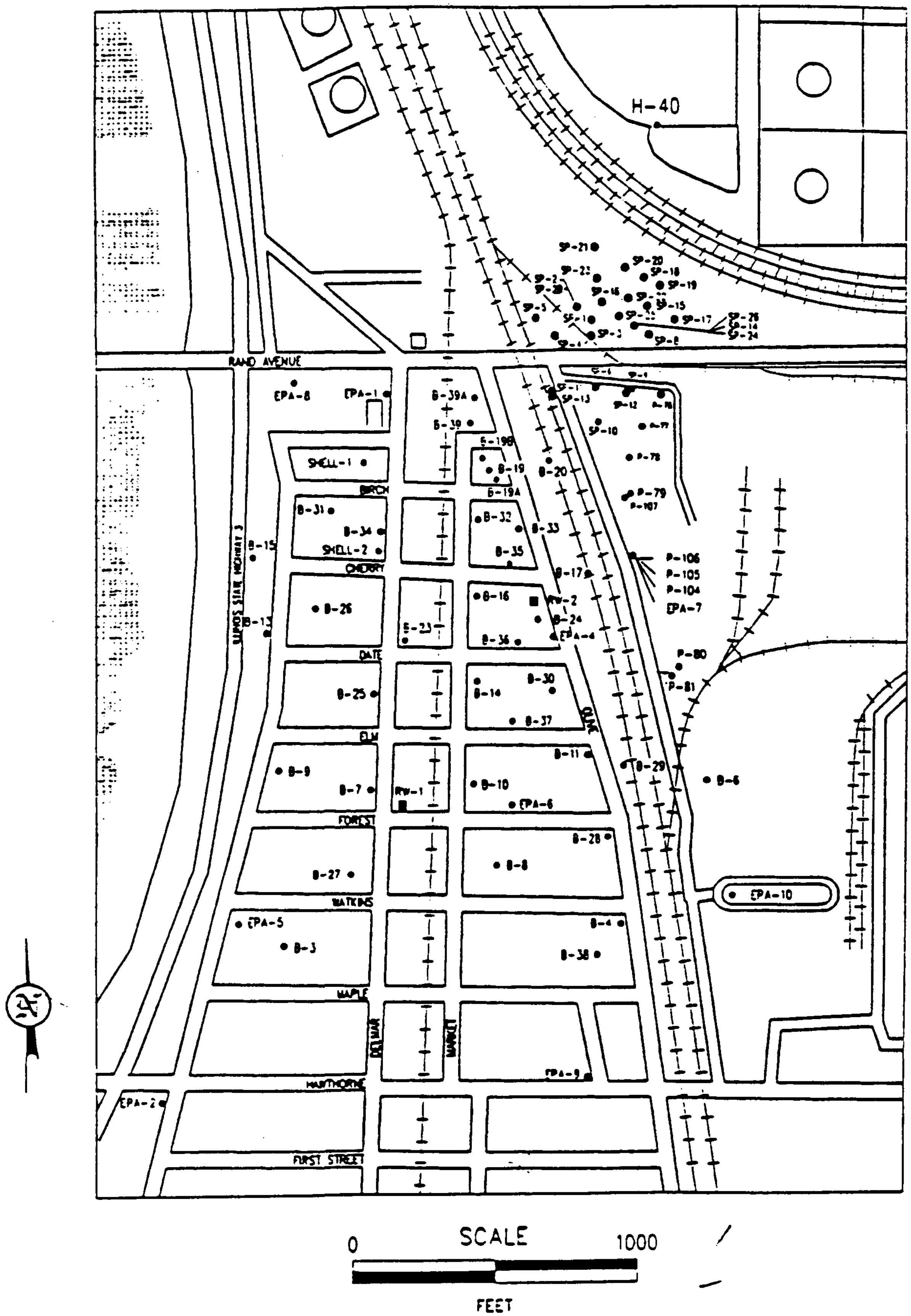


Figure 8

Mathes 1990 Vapor Plume Map

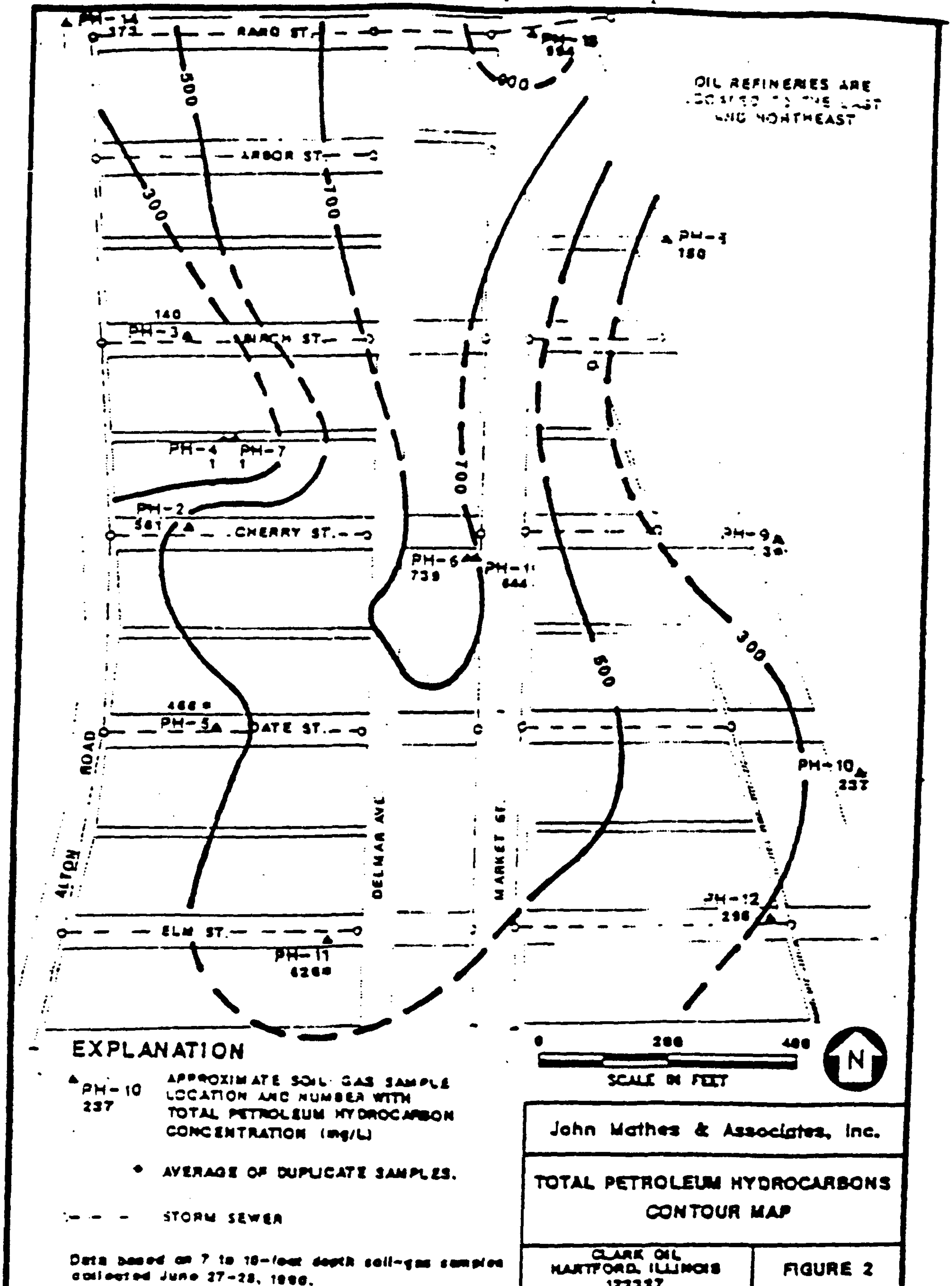
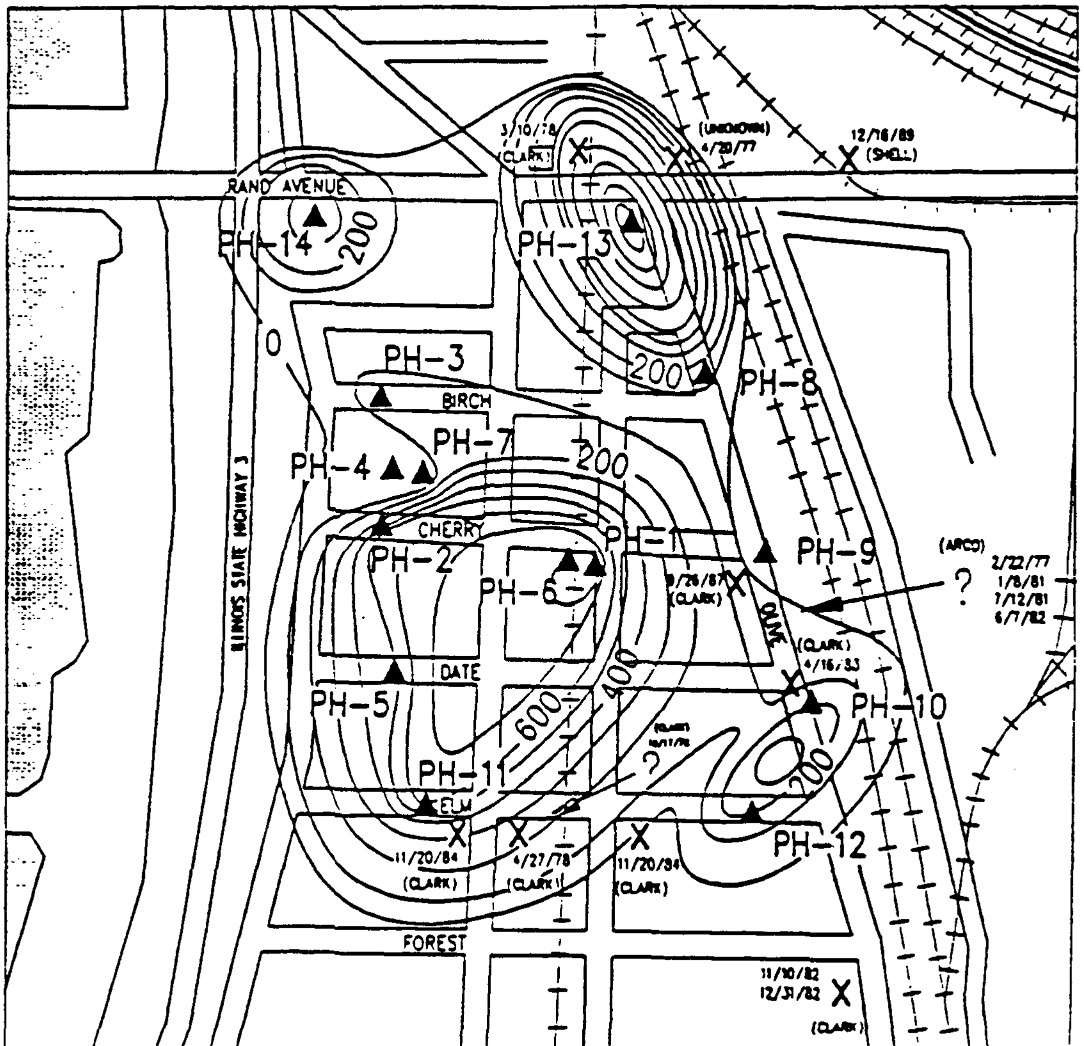


Figure 9

Mathes 1990 Vapor Plume Map (Re-contoured)



SAMPLE LOCATION	DEPTH (feet)	TPH CONCENTRATION (ppmv)
PH-1	8	664
PH-2	7	561
PH-3	7	140
PH-4	7	0.942
PH-5	7	484
PH-6	7	739.2
PH-7	7	0.717
PH-8	9	150
PH-9	9	3.01
PH-10	9	237
PH-11	9	634
PH-12	9	298
PH-13	10	994
PH-14	10	373

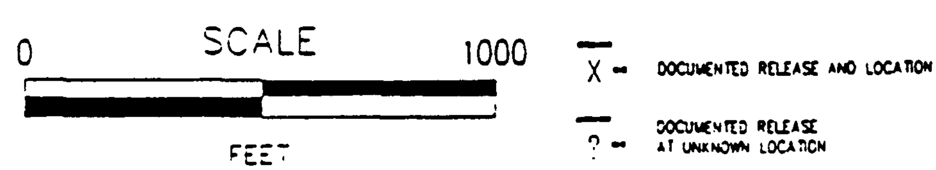
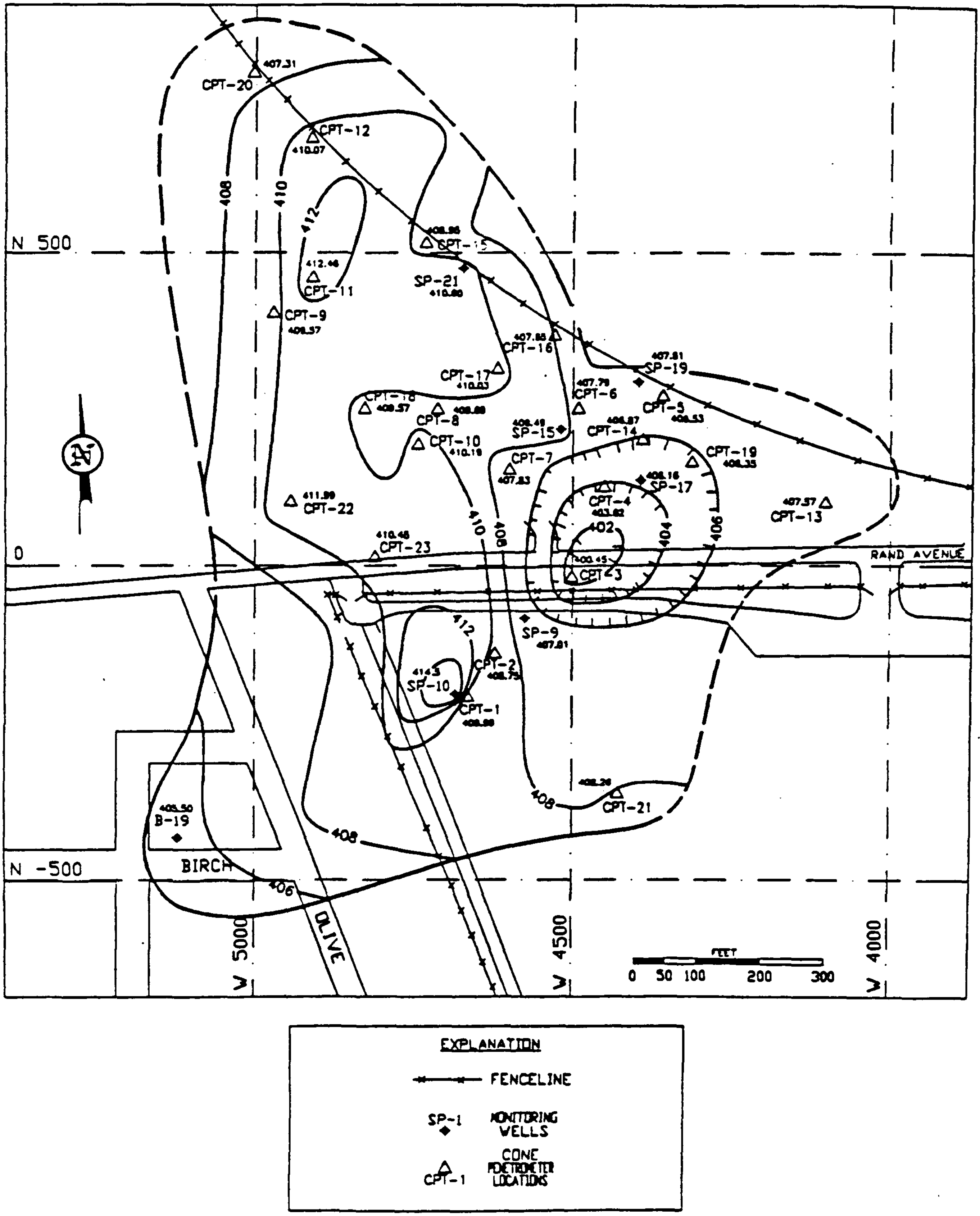


Figure 10

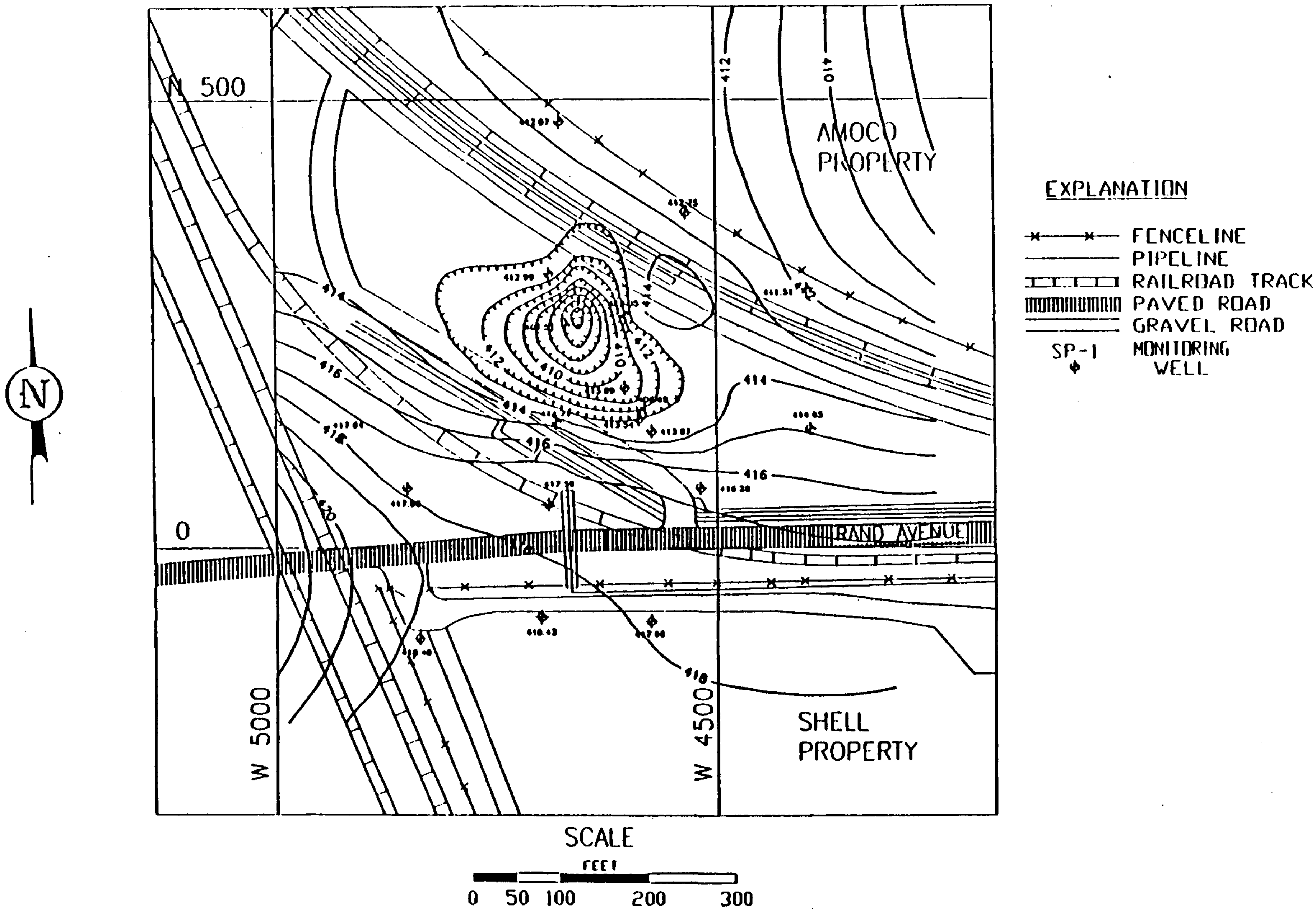
TOP OF THE RAND SAND



RAND-TOP.DWG

FIGURE 11

Rand Avenue Cone-of-Depression Map



RAND731.DWG

FIGURE 12

Cross-Sections Through Hartford

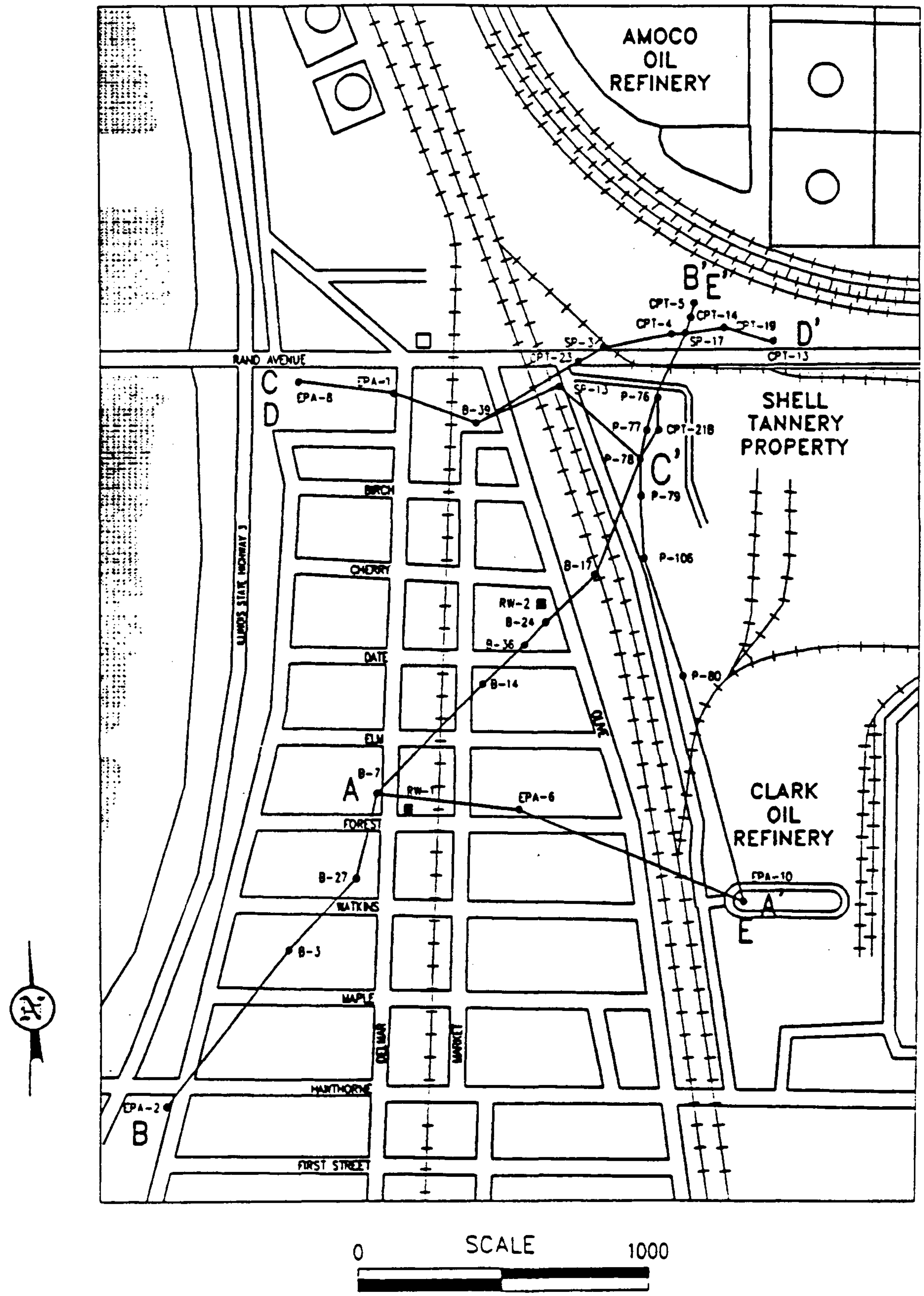


FIGURE 13
CROSS-SECTION A-A'

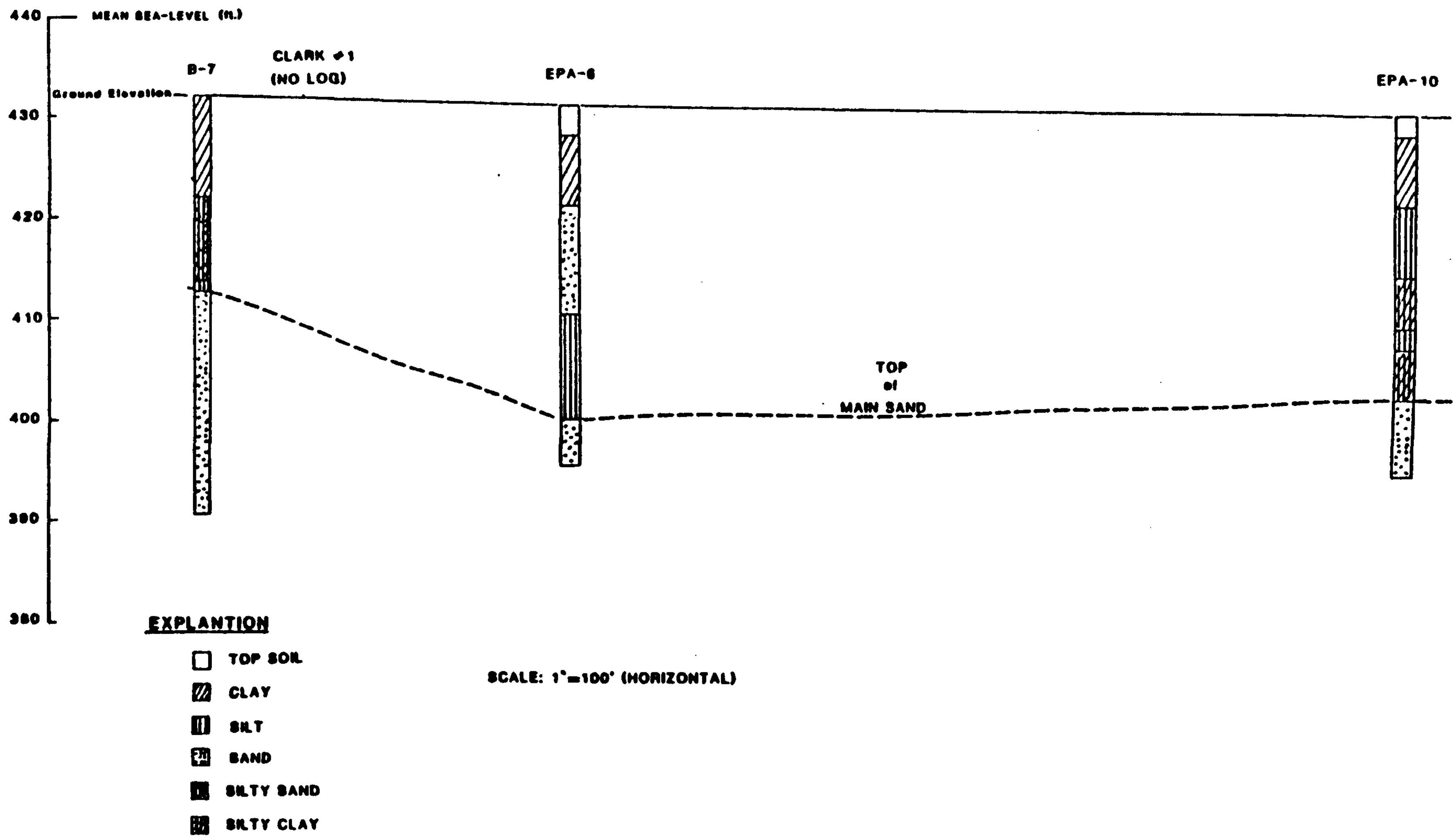
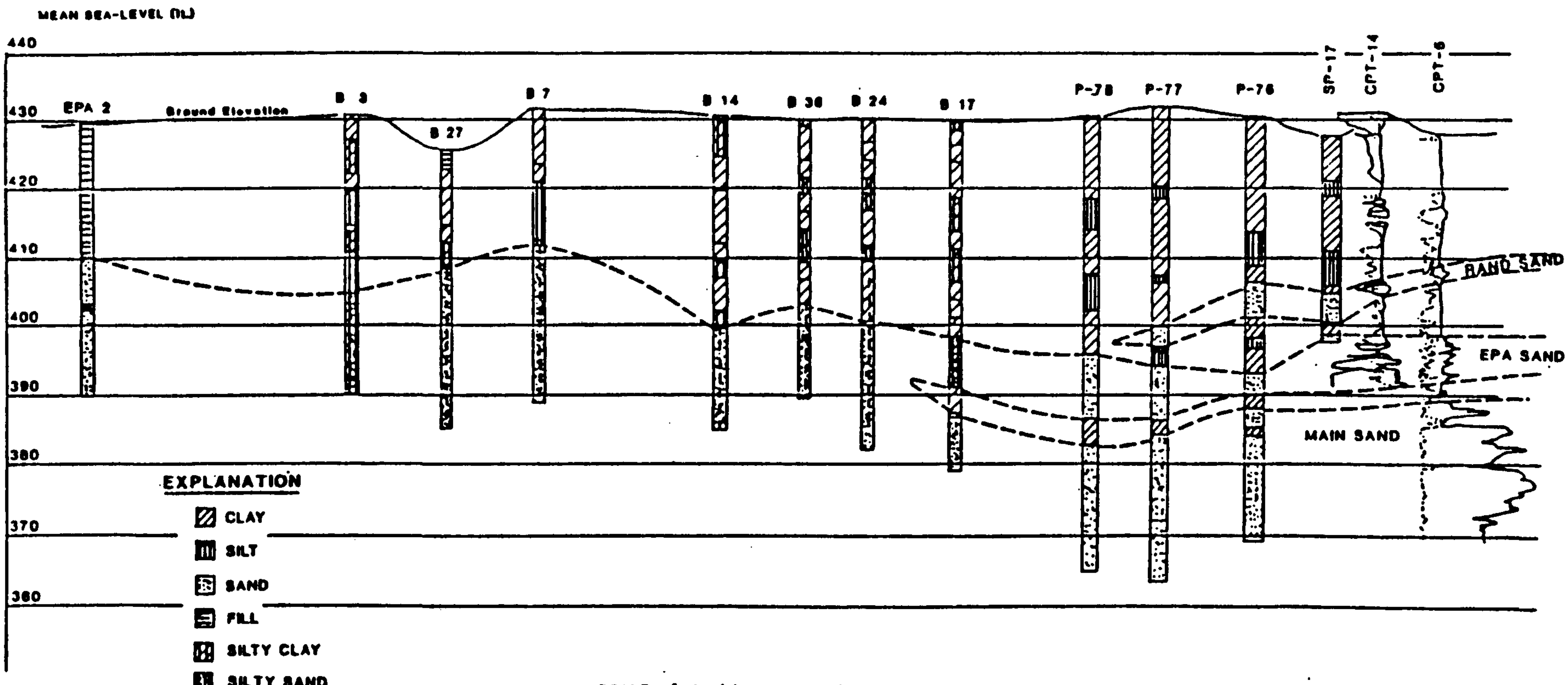


FIGURE 14

CROSS-SECTION B-B'



SCALE: 1"= 300' (HORIZONTAL)

FIGURE 15

CROSS-SECTION C-C'

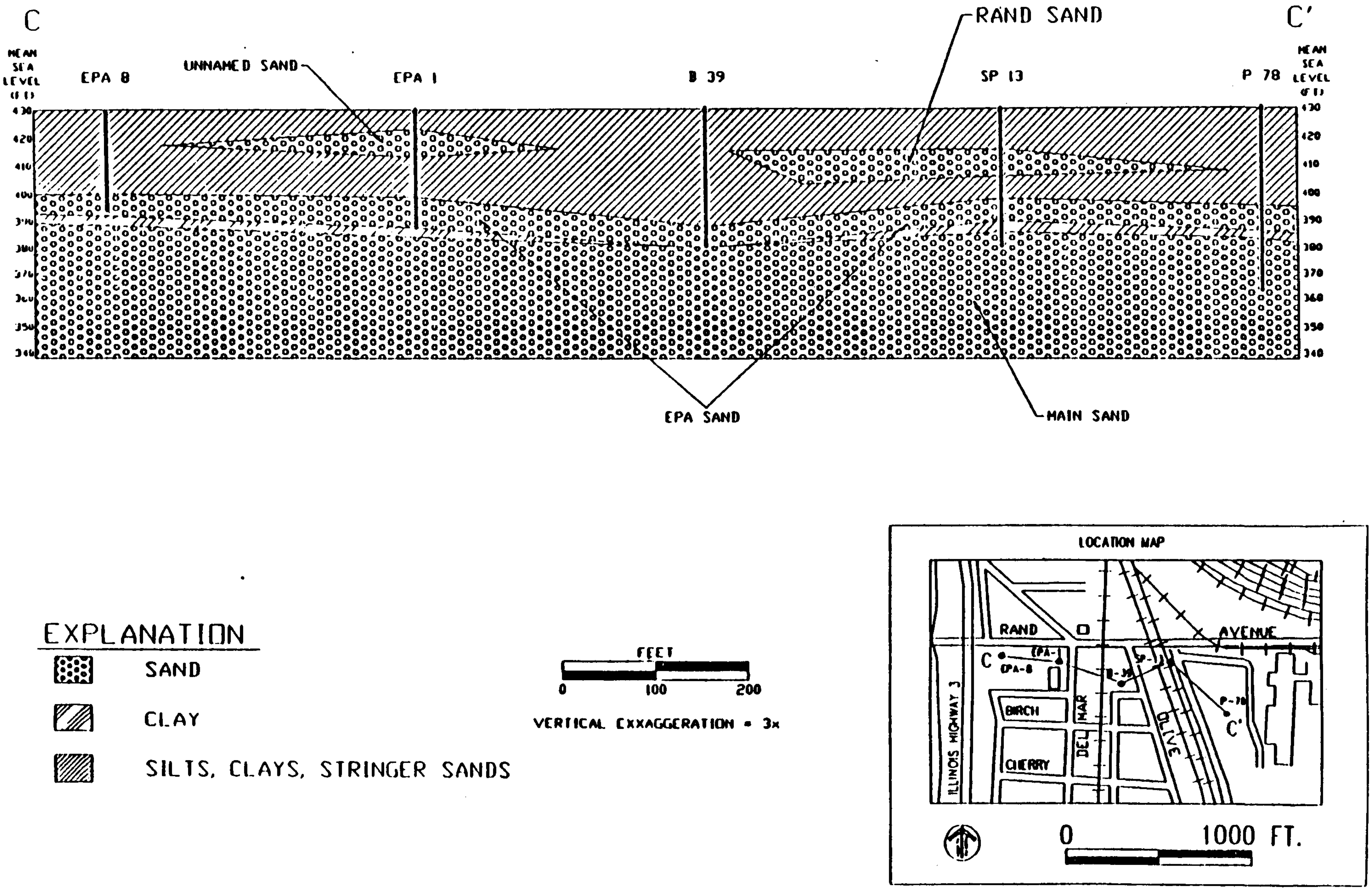


FIGURE 16
CROSS-SECTION D-D'

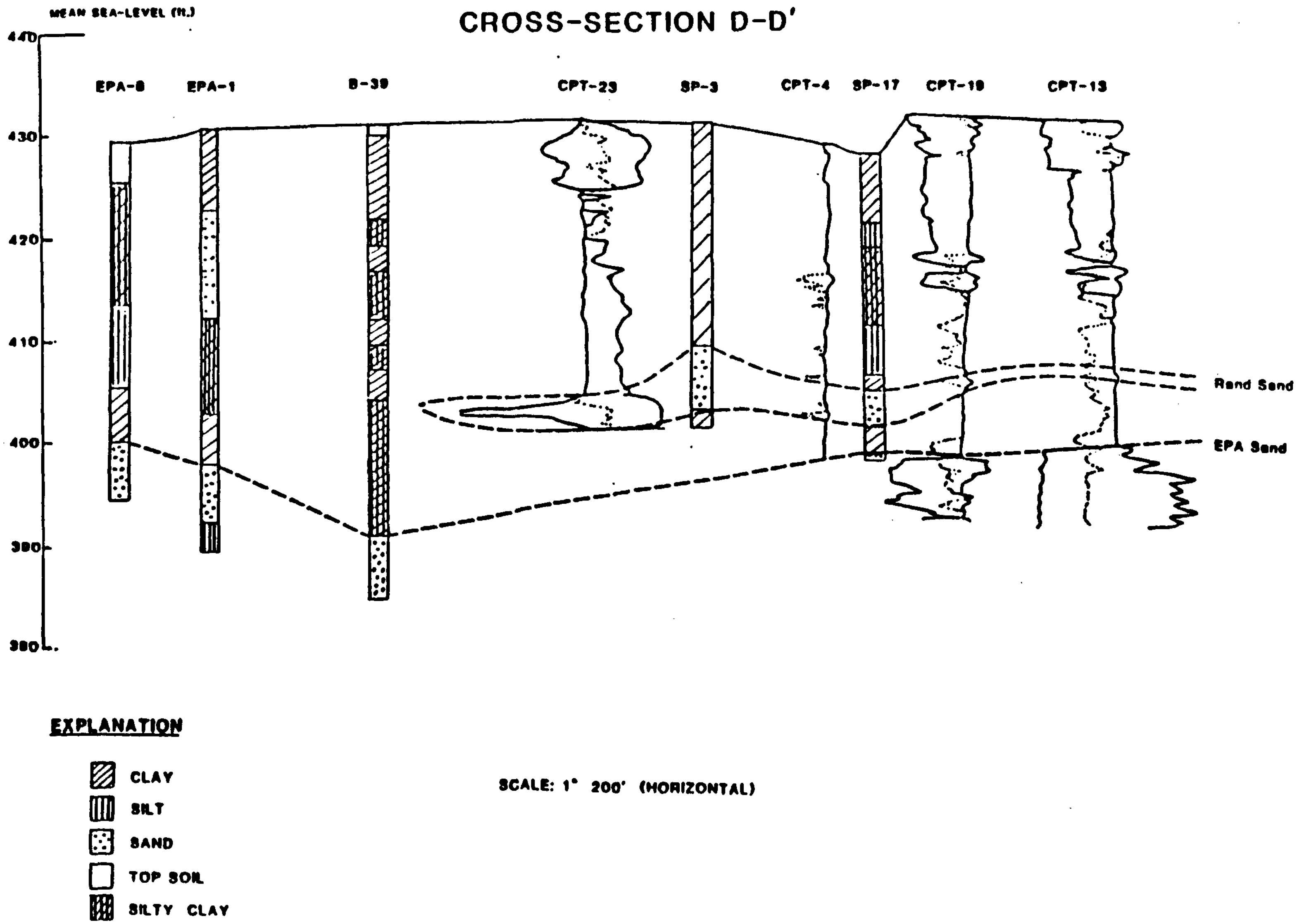
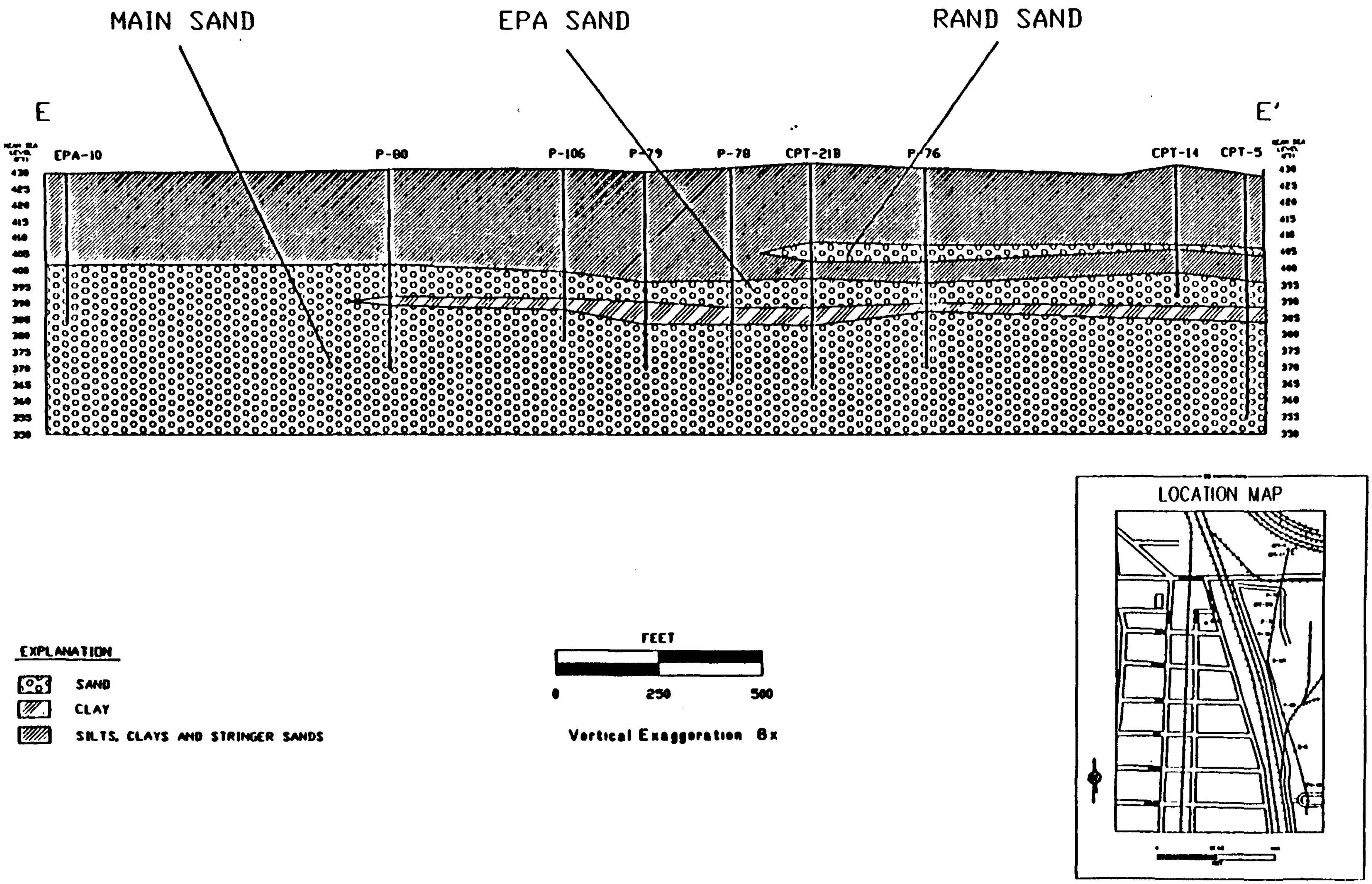


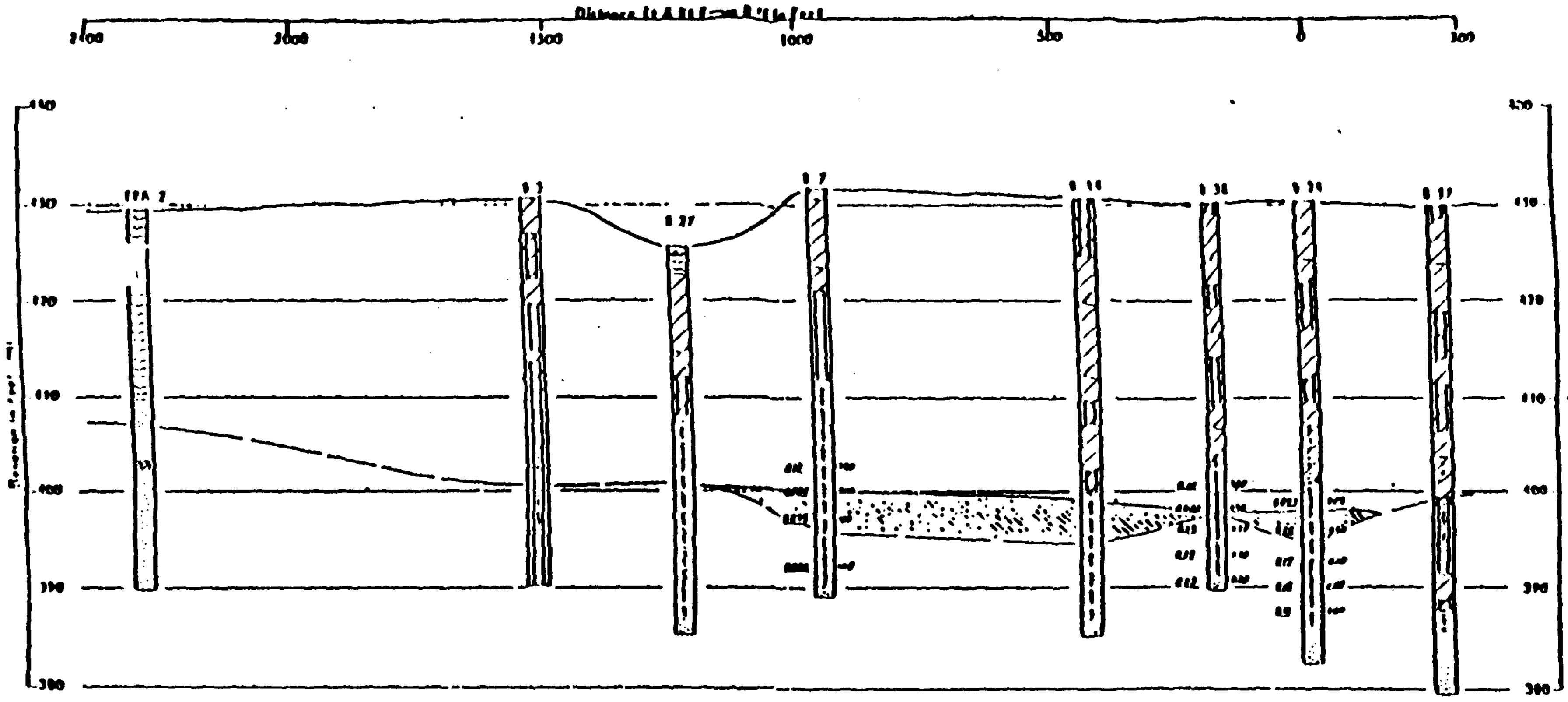
FIGURE 17
CROSS-SECTION E-E'



ES ENGINEERING-SCIENCE

FIGURE 18

Mathes Subsurface Profile, EPA-2 to B-17



54

Figure 19

Mathes Subsurface Profile, B-4 to B-39

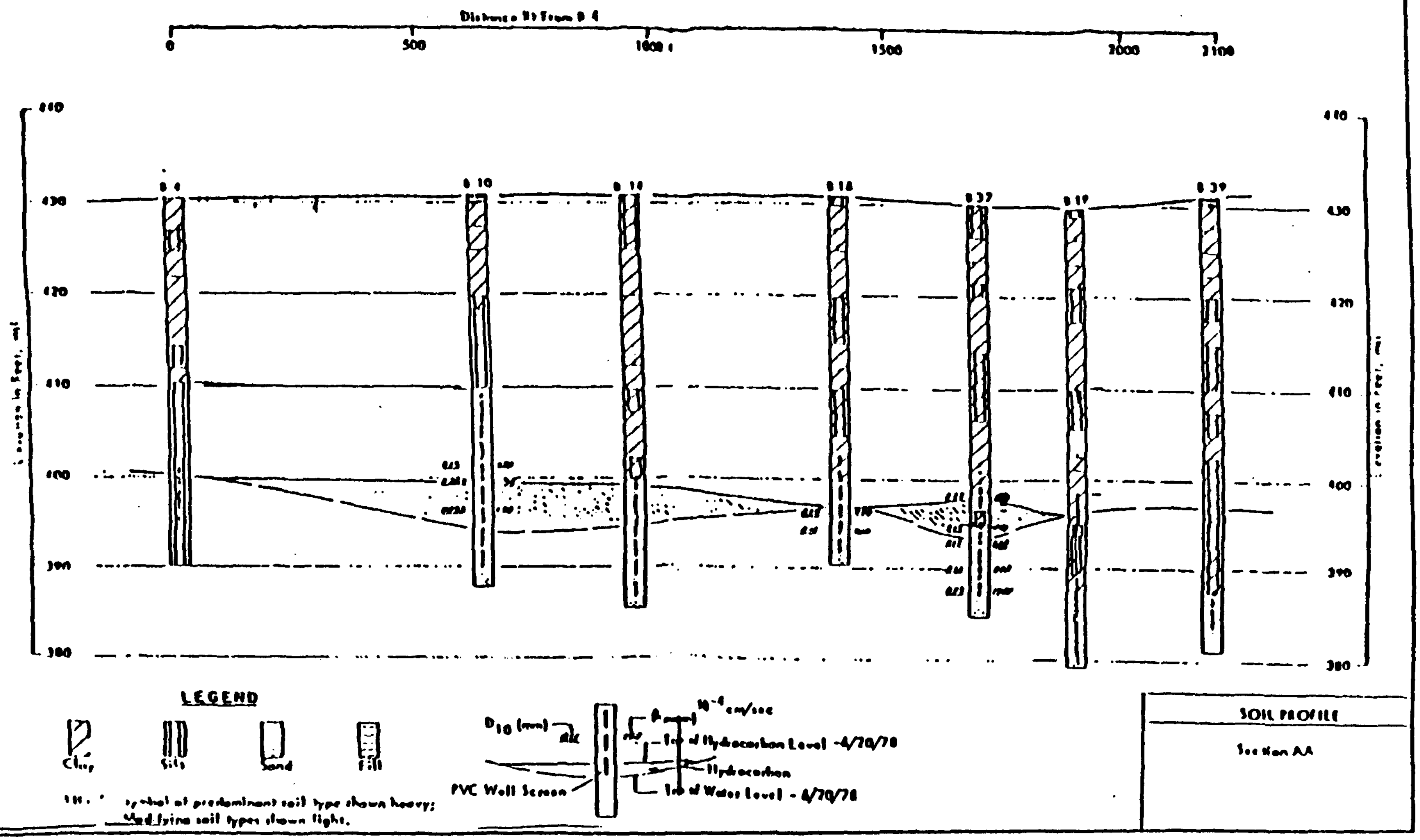
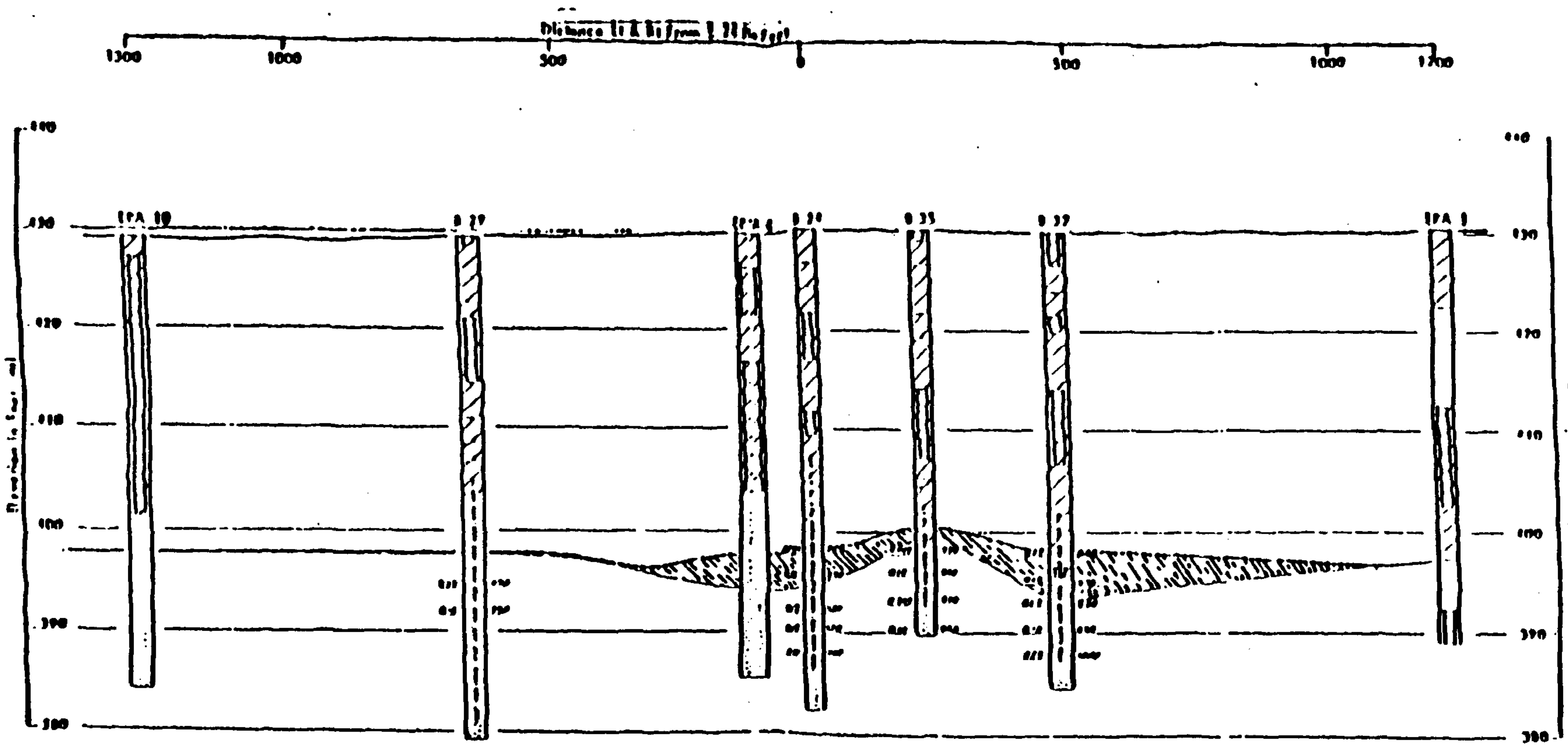


Figure 20

Mathes Subsurface Profile, EPA-10 to EPA-1

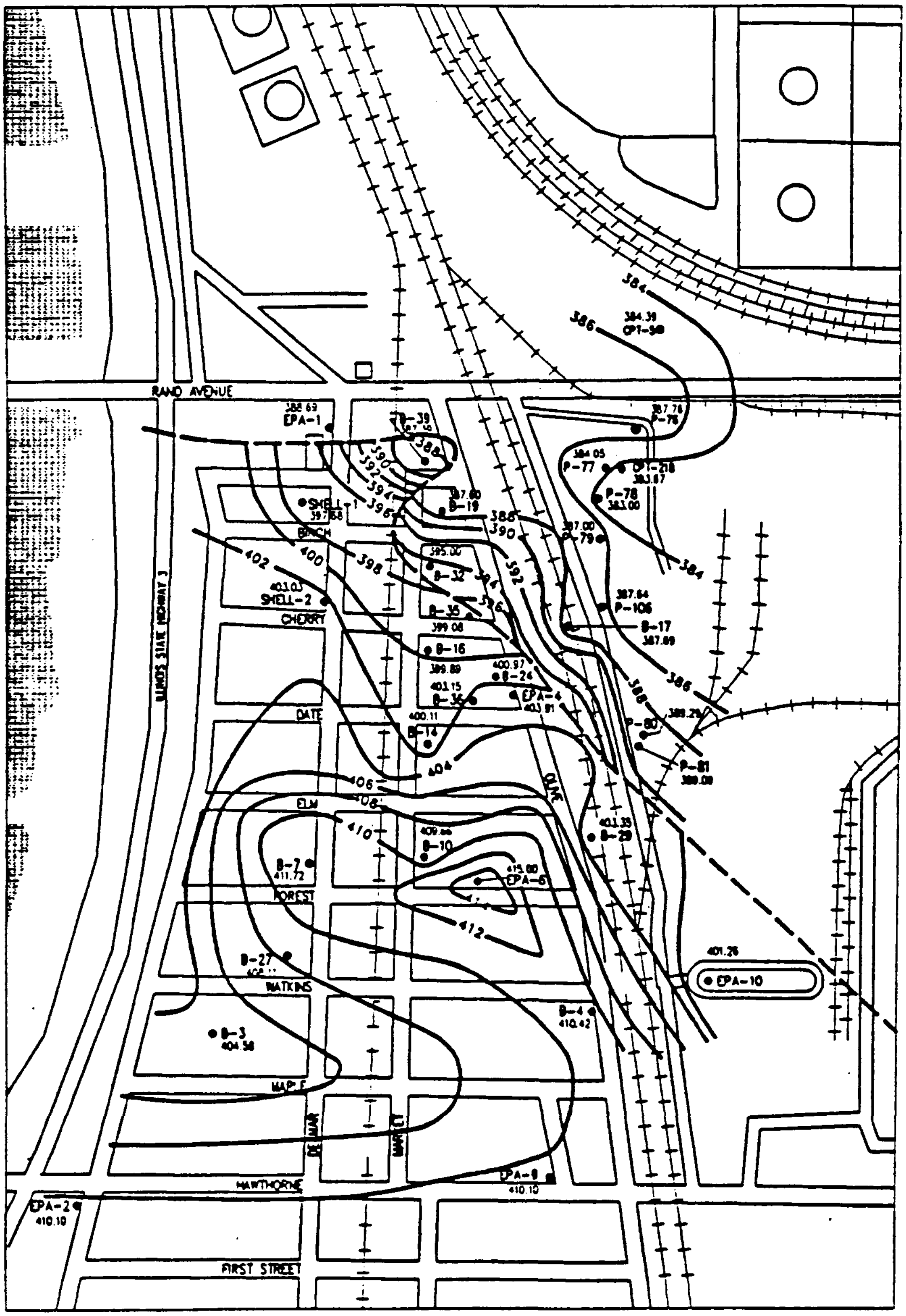


SOIL PROFILE

Section 88

FIGURE 21

TOP OF THE MAIN SAND



EXTENT OF CLAY DELINEATING THE MAIN AND EPA SANDS

SCALE

0 1000

FEET

CONTOUR INTERVAL = 2 FEET

FIGURE 22

Corrected Groundwater Surface of the Main Aquifer-
Third Quarter 1990

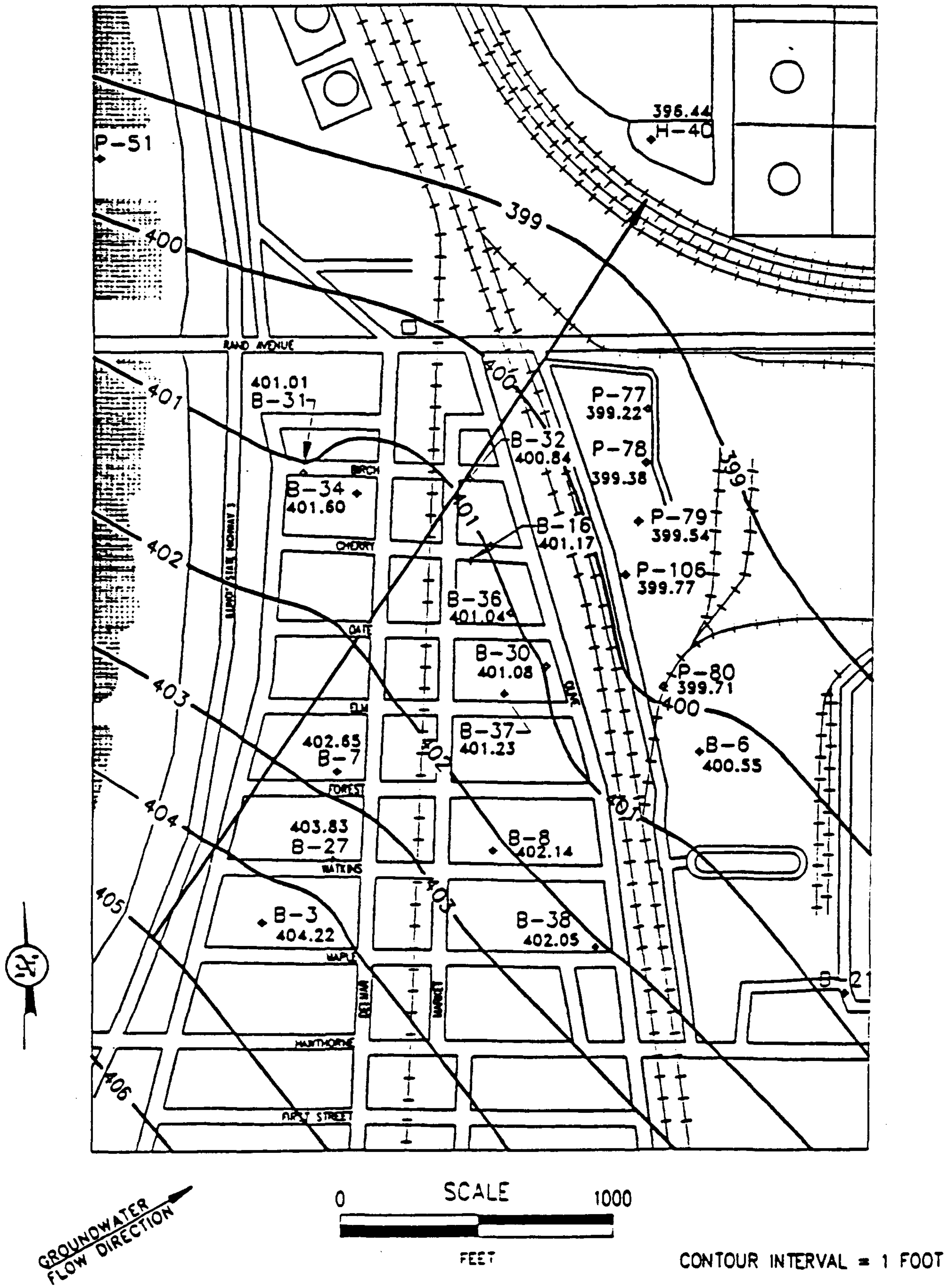
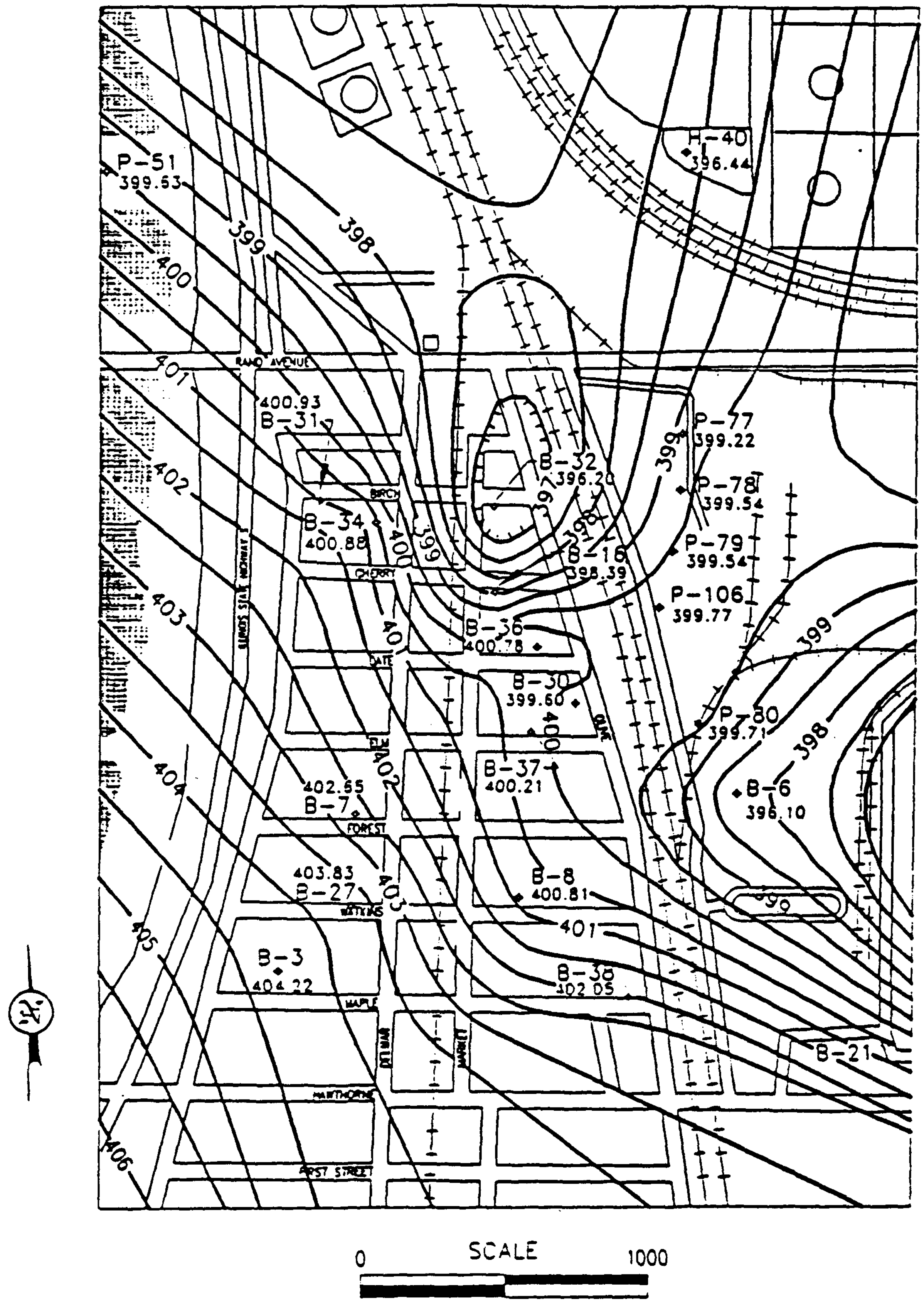


FIGURE 23

Uncorrected Groundwater Surface of the Main Aquifer-
Third Quarter 1990

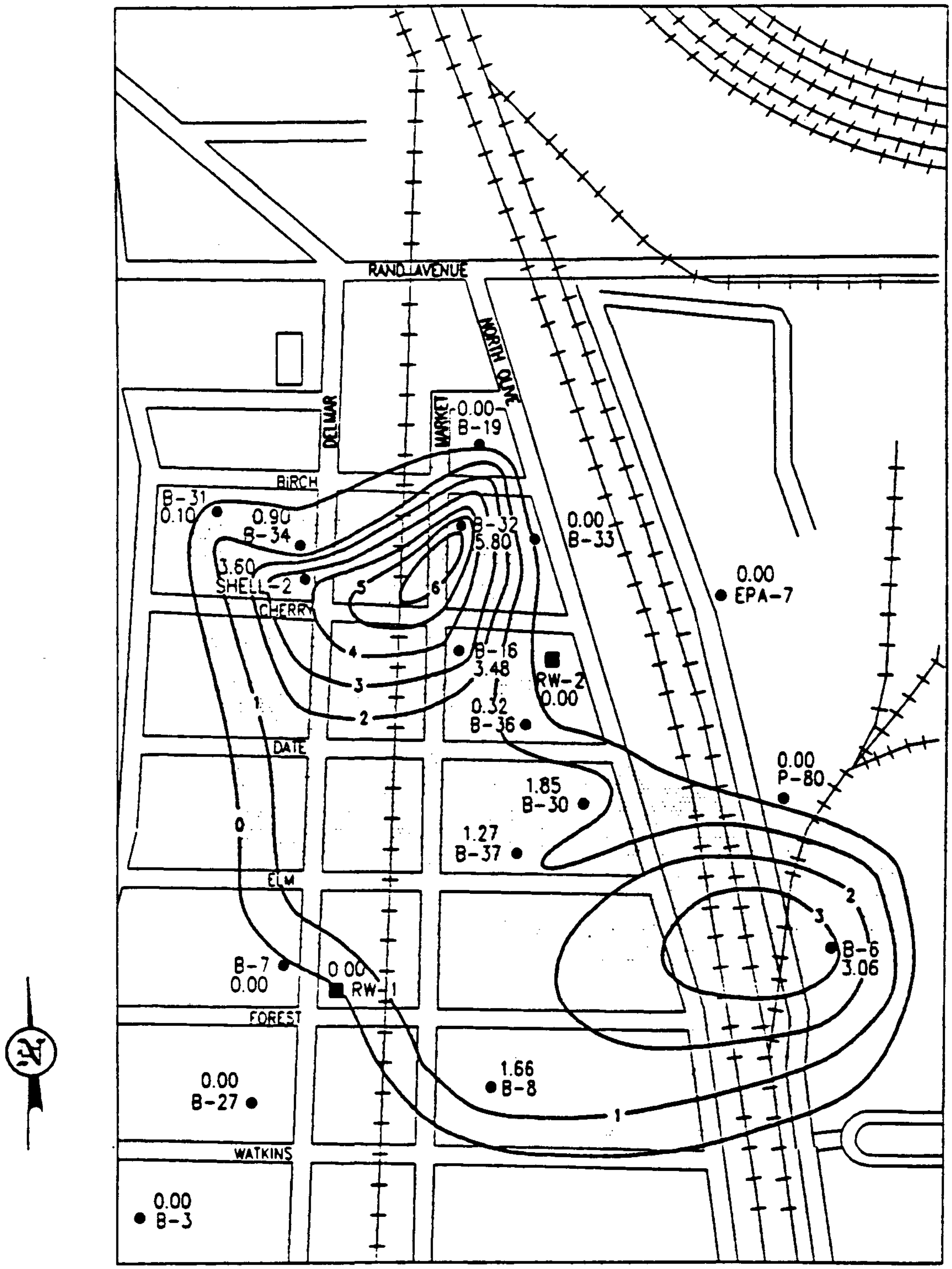


CONTOUR INTERVAL = 0.5 FEET

FIGURE 24

Product Thickness in the Main Aquifer

THIRD QUARTER 1990



CONTOUR INTERVAL = 1 FOOT OF HYDROCARBON ACCUMULATION

B-SERIES GAUGED ON JULY 18, 1990

SCALE 0 — 1000 FEET

EXPLANATION

RAILROAD TRACK

B-8 MONITORING WELL

FIGURE 25

Top of the Main and EPA Sands

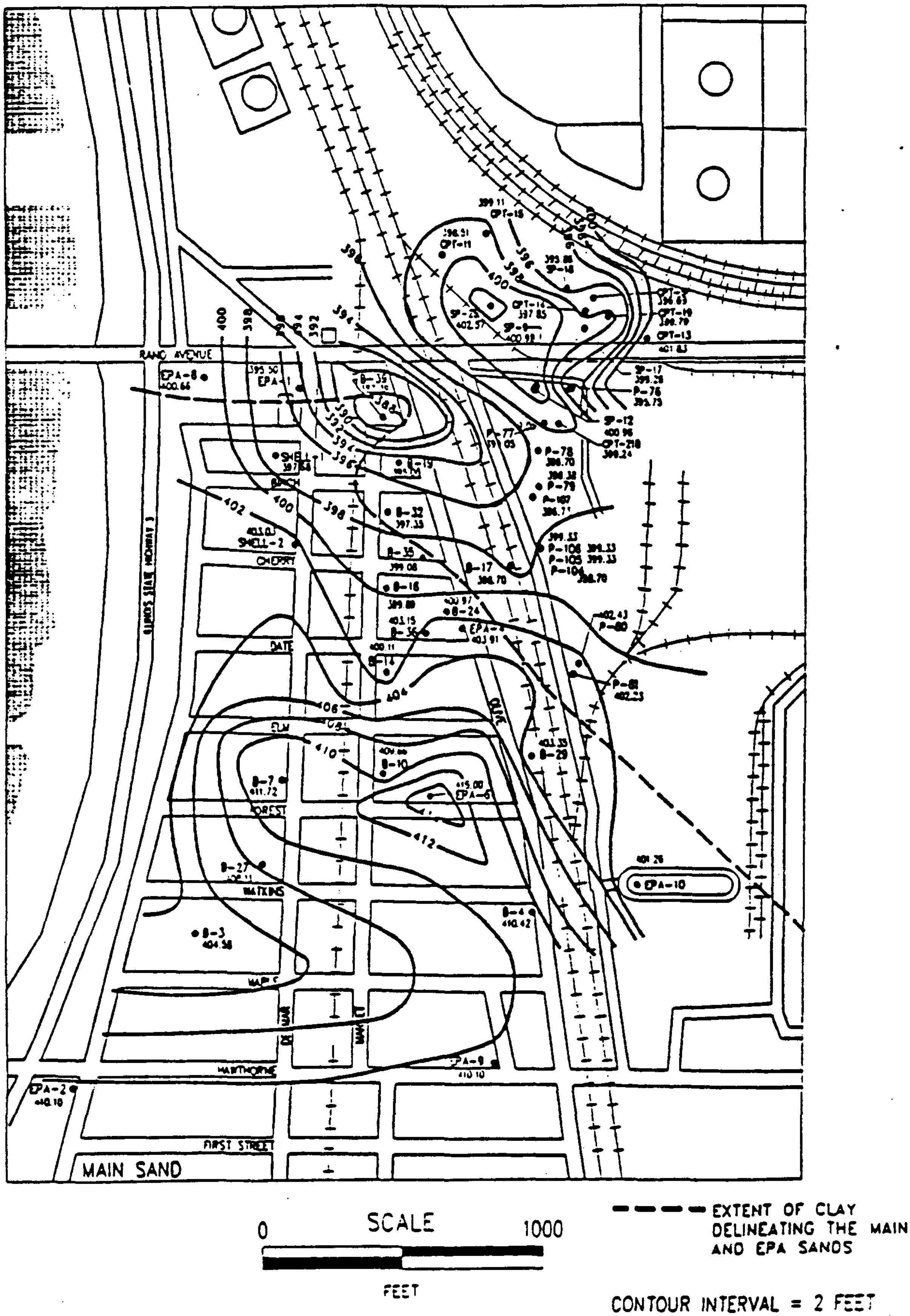
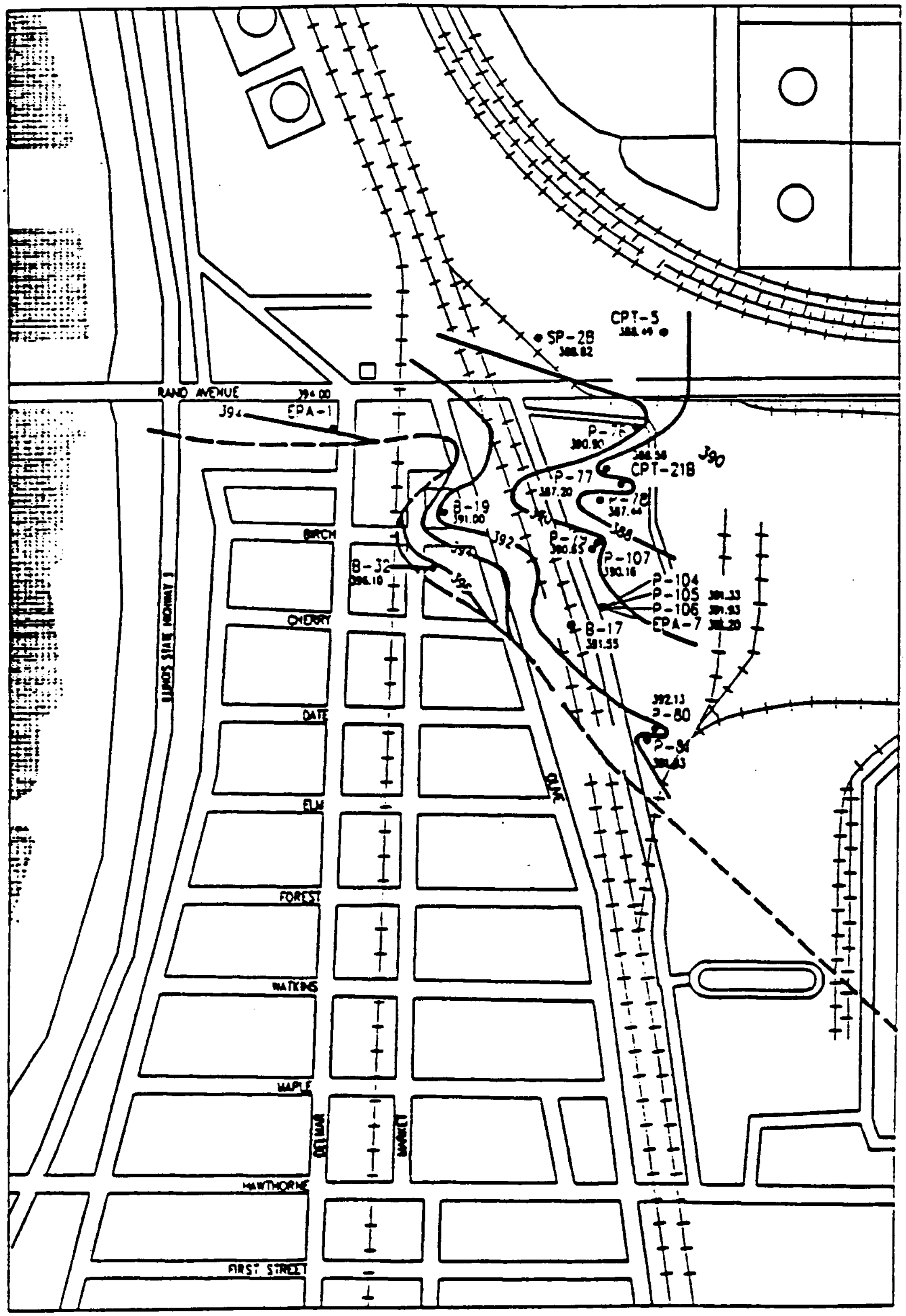


FIGURE 26

Base of the EPA Sand



SCALE

0 1000

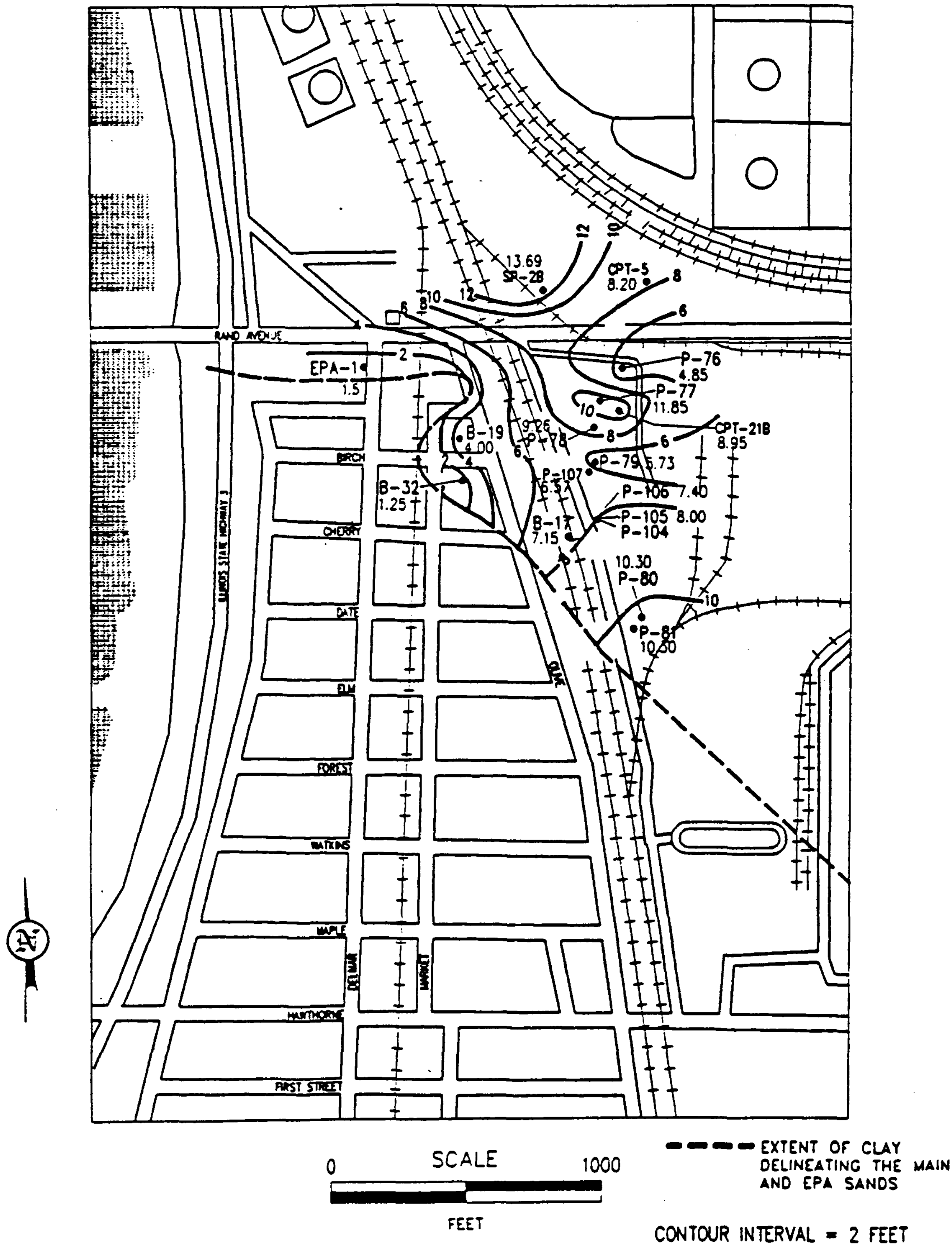
FEET

EXTENT OF CLAY DELINEATING THE MAIN AND EPA SANDS

CONTOUR INTERVAL = 2 FEET

FIGURE 27

ISOPACH THICKNESS OF THE EPA SAND



HO095.42.01/01249E

Table 1
Known Releases In and Adjacent to Hartford

Date	Owner	Location	Product	Comment	Source
1973	Shell	North of Rand	Benzene		Shell Files
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4/20/77	?	Olive and Rand	Fuel Oil	Line repaired on this date	1978 Police Report
3/10/78	Clark	Rand between Delmar and Olive	Gasoline		1978 Police Report
4/27/78	Clark	30' E. of Delmar on Elm	Gasoline	River line failed pressure test on 4/29	1978 Police Report
10/17/78	Clark	Elm	Gasoline	River line	1990 IEPA Report
1/8/81	ARCO		5 BBL gasoline		1990 IEPA Report
7/12/81	ARCO		24 BBL gasoline		1990 IEPA Report
6/7/82	ARCO		9 BBL fuel oil		1990 IEPA Report
11/10/82	Clark	N. Olive at E. Forest	Diesel Oil		1981 - 1990 Police Records
12/31/82	Clark	N. Olive at E. Forest			
4/16/83	Clark	Date at Olive		Overfilled tanks in empty lot at corner of Oak and Olive	1981 - 1990 Police Records
11/24/84	Clark	100 Bk. E. Elm	Light cycle oil	Oil seeping from ground	1990 IEPA Report
9/26/87	Clark	N. Olive at E. Cherry		Overfilled RW-L tank	1981 - 1990 Police Records
12/16/89	Shell	NE of Rand and Olive	294,000 gallons of unleaded		1990 IEPA Report

03/03/92 jeh

Table 2
Dates and Addresses of Hydrocarbon-Related Fires

Date	Address	Resident
April 23, 1970	113 E. Cherry Street	Mr. William Skaggs
March 13, 1973	119 W. Date Street	Mr. Don Tinnon
April 28, 1975	119 E. Watkins	Mr. Robert Mays
March 24, 1978	119 W. Birch St.	Mrs. Rinda Rambo
March 27, 1978	117 W. Birch St.	Mr. Hugh Morse
March 30, 1978	105 W. Cherry St.	Mr. Kenneth Whalen
March 25, 1978	118 E. Date St.	Mr. Gene Overton
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April 1979	4 fires at unknown locations	
July 21, 1981	102 E. Cherry St.	Mr. Harold Settles
June 11, 1985	501 N. Olive St.	Mr. Noah Greer
March 21, 1990	102 E. Cherry (2)	Mr. Harold Settles
May 16, 1990	117 E. Forest St.	Mr. Doug Neal
May 16, 1990	119 W. Birch St.	Ms. Laurie Carnes
May 19, 1990	117 E. Forest St.	Mr. Doug Neal
May 20, 1990	101 E. Birch St.	Mr. Jeff Bartlett

TABLE 3
MONITOR WELLS OF THE HARTFORD VICINITY
3rd QUARTER 1990 GAUGING DATA AND AQUIFER ELEVATIONS

WELL ID	TOP OF WELL MSL ft	DEPTH TO PRODUCT ft	DEPTH TO WATER (Static)* ft	UNCORR. WT ELEV ft	PRODUCT ELEV. ft	PRODUCT THICKNESS ft	WT ELEV CORRECTED FOR PRODUCT ft	TOP OF RAND SAND ft	BASE OF RAND SAND ft	TOP OF EPA SAND ft	BASE OF EPA SAND ft	TOP OF MAIN SAND ft	SCREENED AQUIFER
SHELL WELLS – TANNERY PROPERTY													
P-76	433.88		34.67	399.21			399.21	407.03	402.14	395.75	390.90	387.75	EPA-MAIN
P-77	435.17		35.95	399.22			399.22	406.00	403.57	399.05	387.20	384.05	MAIN
P-78	433.88		34.50	399.38			399.38	–	–	396.70	387.44	383.00	MAIN
P-79	433.26		33.72	399.54			399.54	–	–	396.38	390.65	387.00	MAIN
P-80	433.64		33.93	399.71			399.71	–	–	402.43	392.13	389.29	MAIN
P-81	433.80	32.42	34.21	399.59	401.38	1.79	401.02	–	–	402.23	391.93	389.09	EPA
P-104	433.28		17.54	415.74			415.74	–	–				UNNAMED
P-105	433.13	31.39	32.95	400.18	401.74	1.56	401.43	–	–	399.33	391.33		EPA
P-106	433.24		33.47	399.77			399.77	–	–	399.33	391.93	387.64	MAIN
P-107	432.46		27.70	404.76			404.76	–	–	396.73	390.16		EPA
EPA-7**	431.39		30.33	401.06			401.06	–	–	394.70	391.20	385.20	EPA-MAIN
SHELL WELLS AND CPTs – RAND AVENUE													
SP-1	429.63		8.76	420.87			420.87	•	•				RAND
SP-2(D)**	429.84		NM	NM			NM	•	•	•	•		RAND-EPA
SP-2B(D)	429.69		NM	NM			NM	409.69	405.45	402.51	388.82		EPA
SP-3	432.26		10.33	421.93			421.93	•	•				RAND
SP-4	430.91		9.22	421.69			421.69	•	•				RAND
SP-5	431.46		9.68	421.78			421.78	•	•				RAND
SP-6	433.63		12.66	420.97			420.97	•	•				RAND
SP-7	429.48		8.67	420.81			420.81	•	•				RAND
SP-8	429.53		8.69	420.84			420.84	•	•				RAND
SP-9	433.15		12.78	420.37			420.37	407.01	405.99	400.98			RAND
SP-10	433.19		12.28	420.91			420.91	414.50	407.21				RAND
SP-11	433.00		11.52	421.48			421.48	•	406.10				RAND
SP-12 (D)	432.92		28.34	404.58			404.58	407.01	405.99	400.98	•	•	EPA-MAIN
SP-13 (D)	433.27		30.32	402.95			402.95	•	406.10	•	•	•	EPA-MAIN
SP-14 (D)	429.33		27.73	401.60			401.60	•	•	•	•	•	EPA-MAIN
SP-15	428.96	10.22	10.27	418.69	418.74	0.05	418.73	409.49	405.63				RAND
SP-16	428.77		8.81	419.96			419.96	•	•				RAND
SP-17	428.68		10.51	418.17			418.17	404.16	401.94	399.26			RAND
SP-18 (D)	429.01		27.74	401.27			401.27	–	–	395.86	•	•	EPA-MAIN
SP-19	431.61		17.49	414.12			414.12	407.61	405.39				RAND
SP-20	431.88		15.92	415.96			415.96	409.41	406.52				RAND
SP-21	432.42		16.58	415.84			415.84	410.60	404.41				RAND
SP-22	430.91		12.41	418.50			418.50	•	•				RAND
SP-23	431.27		12.82	418.45			418.45	•	•				RAND
SP-24	429.46		8.60	420.86			420.86	•	•				RAND
SP-25	429.00	8.48	8.85	420.15	420.52	0.37	420.45	•	•				RAND
SP-26	428.99	8.36	8.55	420.44	420.63	0.19	420.59	•	•				RAND
CPT-1	430.50			NM			NM	409.99	405.07				
CPT-2	430.28			NM			NM	408.75	404.03				
CPT-3	431.88			NM			NM	406.45	400.71				
CPT-4	429.06			NM			NM	403.62	402.65				
CPT-5	428.68			NM			NM	406.53	404.89	396.69	388.49	384.39	
CPT-6	431.58			NM			NM	407.79	406.97				

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WELL ID	TOP OF WELL MSL ft	DEPTH TO PRODUCT ft	DEPTH TO WATER (Static)* ft	UNCORR. WT ELEV ft	PRODUCT ELEV. ft	PRODUCT THICKNESS ft	WT ELEV CORRECTED FOR PRODUCT ft	TOP OF RAND SAND ft	BASE OF RAND SAND ft	TOP OF EPA SAND ft	BASE OF EPA SAND ft	TOP OF MAIN SAND ft	SCREENED AQUIFER
CPT-7	429.98			NM			NM	407.83	403.73				
CPT-8	429.38			NM			NM	409.69	404.77				
CPT-9	430.08			NM			NM	409.57	401.37				
CPT-10	429.88			NM			NM	410.19	406.09				
CPT-11	430.50			NM			NM	412.46	404.25	398.51			
CPT-12	430.58			NM			NM	410.07	404.33				
CPT-13	432.18			NM			NM	407.57	405.11	401.83			
CPT-14	431.48			NM			NM	406.87	405.23	397.85			
CPT-15	430.28			NM			NM	408.95	405.67	399.11			
CPT-16	428.98			NM			NM	407.65	406.01				
CPT-17	431.38			NM			NM	404.31	403.49				
CPT-18	430.08			NM			NM	409.57	405.47				
CPT-19	431.78			NM			NM	406.35	405.53	399.79			
CPT-20	430.28			NM			NM	407.31	401.57				
CPT-21B	432.05			NM			NM	408.26	402.52	399.24	388.58	383.67	
CPT-22	431.68			NM			NM	411.99	402.97				
CPT-23	431.78			NM			NM	410.45	404.71				
AMOCO WELLS													
H-40	435.14		36.70	398.44			398.44	–	–	UNK.	UNK.	UNK.	MAIN
WELLS – VILLAGE OF HARTFORD													
B-3	431.27		27.05	404.22			404.22	–	–	–	–	404.58	MAIN
B-4	430.00			NM			NM	–	–	–	–	410.42	MAIN
B-7	432.98		30.33	402.65			402.65	–	–	–	–	411.72	MAIN
B-8	432.31	29.84	31.50	400.81	402.47	1.66	402.14	–	–	–	–	UNK.	MAIN
B-10	432.00			NM			NM	–	–	–	–	409.86	MAIN
B-14	432.00			NM			NM	–	–	–	–	400.11	MAIN
B-16	432.09	30.22	33.70	398.39	401.87	3.48	401.17	–	–	–	–	399.89	MAIN
B-17	430.00			NM			NM	–	–	398.70	391.55	387.69	MAIN
B-19	430.98		14.60	416.38			416.38	405.50	402.65	395.00	391.00	387.60	EPA-MAIN
B-24	432.21			432.21			432.21	–	–	–	–	400.97	MAIN
B-27	426.51		22.68	403.83			403.83	–	–	–	–	406.11	MAIN
B-29	429.00			NM			NM	–	–	–	–	403.35	MAIN
B-30	431.75	30.30	32.15	399.60	401.45	1.85	401.08	–	–	–	–	UNK.	MAIN
B-31	432.78	31.75	31.85	400.93	401.03	0.10	401.01	–	–	–	–	UNK.	MAIN
B-32	430.75	28.75	34.55	396.20	402.00	5.80	400.84	–	–	397.35	396.10	395.17	EPA-MAIN
B-33	430.86		28.65	402.21			402.21	–	–	–	–	UNK.	EPA-MAIN
B-34	432.63	30.85	31.75	400.88	401.78	0.90	401.60	–	–	–	–	UNK.	MAIN
B-35	430.68			NM			NM	–	–	–	–	399.08	MAIN
B-36	431.18	30.08	30.40	400.78	401.10	0.32	401.04	–	–	–	–	403.15	MAIN
B-37	432.41	30.93	32.20	400.21	401.48	1.27	401.23	–	–	–	–	UNK.	MAIN
B-38	430.60		28.55	402.05			402.05	–	–	–	–	UNK.	MAIN
B-39	433.00			NM			NM	–	–	–	–	387.39	MAIN
SHELL-1	431.18			NM			NM	–	–	–	–	403.15	MAIN
SHELL-2	432.62	30.50	34.10	398.52	402.12	3.60	401.40	–	–	–	–	UNK.	MAIN
RW-1	434.44		32.05	402.39			402.39	–	–	–	–	UNK.	MAIN
RW-2	432.66		31.95	400.71			400.71	–	–	–	–	387.39	MAIN

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IEPA WELLS – VILLAGE OF HARTFORD													
EPA-1	430.50			NM			NM	–	–	395.50	394.00	388.69	EPA
EPA-2	429.60			NM			NM	–	–	–	–	410.10	MAIN
EPA-4	430.00			NM			NM	–	–	–	–	403.91	MAIN
EPA-5	429.40			NM			NM	–	–	–	–		MAIN
EPA-6	430.80			NM			NM	–	–	–	–	415.00	MAIN
EPA-7**	LOCATED AND LISTED AS A SHELL TANNERY PROPERTY WELL							–	–	394.70	391.20	385.20	EPA-MAIN
EPA-8	429.66			NM			NM	–	–	400.66			EPA
EPA-9	430.10			NM			NM	–	–	–	–	410.10	MAIN
EPA-10	429.20			NM			NM	–	–	–	–	401.26	MAIN
CLARK REFINERY WELLS													
B-3	431.56		30.35	401.21			401.21	–	–	UNK.	UNK.	UNK.	MAIN
B-6	432.69	31.53	34.59	398.10	401.16	3.06	400.55	–	–	UNK.	UNK.	UNK.	MAIN
B-27	430.91		26.99	403.92			403.92	–	–	UNK.	UNK.	UNK.	MAIN
B-21	431.46	30.61	30.71	400.75	400.85	0.10	400.83	–	–	UNK.	UNK.	UNK.	MAIN

	ELEVATION WAS ESTIMATED FROM BORING LOG OR CROSS-SECTION
	SAND UNIT WAS NOT PENETRATED. ELEVATION UNKNOWN.
–	SAND UNIT IS NOT PRESENT AT THIS WELL LOCATION
*	SAND UNIT SURFACE FELL BETWEEN SAMPLES. CPT DATA USED FOR DELINEATING RAND SAND
**	WELL SP-2 AND EPA-7 PLUGGED AND ABANDONED 10/21/91
NM	WELL WAS NOT GAUGED
UNK.	ELEVATION UNKNOWN. BORING LOGS NOT AVAILABLE.

Table 4
Site Monitoring Data

Well No.	Depth to Fluid (ft)	Depth to Water (ft)	Product Thickness (ft)
SP-1	-	15.85	-
SP-3	-	16.36	-
SP-7	15.13	16.69	1.56
SP-16	-	15.48	-
SP-8	-	16.36	-
SP-15	15.16	16.55	1.39
SP-17	-	16.04	-
SP-4	-	16.85	-
SP-5	-	17.33	-

Table 5
Site Monitoring Data

Well No.	Depth to Fluid	Depth to Water	Product Thickness
SP-3	-	7.51	-
SP-7	-	6.64	-
SP-16	-	7.61	-
SP-8	-	6.53	-
SP-15	7.49	8.09	0.60
SP-17	-	8.50	-
SP-4	-	6.14	-
SP-5	-	5.56	-
SP-14	-	27.05	-
SP-24	-	-	-
SP-25	6.19	7.61	1.42
SP-26	6.04	6.06	0.02

Table 6
Summary of Geotechnical Test Results
Rand Avenue Spill Site
October 22, 1991

Boring Number	Sample Number	Sample Depth (Feet)	Natural Moisture Content (Percent)	Dry Unit Weight (pcf)	Specific Gravity	Porosity (Percent)	Vertical Hydraulic Conductivity (cm/sec)
B-1	S-1	17.5 - 18.0	30.8	83.5	2.63	49.1	NT
B-1	S-2	19.0 - 21.0	34.1	NT	2.67	NT	NT
B-1	S-3	23.0 - 25.0	36.9	NT	2.66	NT	NT
B-1	S-4-1	25.5 - 26.0	34.2	85.5	2.60	47.3	NT
B-1	S-4-2	26.0 - 26.5	52.4	65.3	NT	NT	2.9 x 10^{-8}
B-1	S-4-3	26.5 - 27.0	48.8	71.7	2.69	57.3	NT
B-2	S-1	18.0 - 20.0	29.1	NT	2.69	NT	NT
B-2	S-2	20.0 - 22.0	39.0	NT	2.66	NT	NT
B-2	S-3-1	22.5 - 23.0	34.3	82.0	NT	NT	2.0 x 10^{-5}
B-2	S-3-2	23.0 - 24.0	36.6	81.4	2.74	52.4	NT
B-3	S-1	18.5 - 19.0	33.6	72.3	2.63	55.9	NT
B-3	S-2	20.0 - 22.0	32.9	NT	2.65	NT	NT
B-3	S-3	24.0 - 26.0	31.6	NT	2.67	NT	NT

pcf Pounds per cubic foot.
NT Not tested.

Table 7
Summary of Grain-size Distribution Analysis
Rand Avenue Spill Site
October 22, 1991

Boring Number	Sample Number	Sample Depth (Feet)	Relationship to Rand Sand	% Sand	Composition % Silt	% Clay	Description
B-1	S-1	17.5 - 18.0	Above	6	71	23	Dark gray-brown silty clay, trace sand, CL
B-1	S-2	19.0 - 21.0	In	70	21	9	Dark gray-brown silty sand, SM
B-1	S-3	23.0 - 25.0	Base	35	58	7	Dark gray-brown sandy silt, SM
B-1	S-4-1	25.5 - 26.0	Contact	13	60	27	Dark gray-brown silty clay, trace sand, CL
B-1	S-4-3	26.5 - 27.0	Below	1	2	77	Dark gray-brown clay with silt, CH
B-2	S-1	18.0 - 20.0	Above	4	67	29	Gray-brown silty clay, trace sand, CL
B-2	S-2	20.0 - 22.0	In	8	75	17	Dark gray-brown silt, trace sand, ML
B-2	S-3-2	23.0 - 24.0	Contact	0	45	55	Dark gray-brown clay with silt, CH
B-3	S-1	18.5 - 19.0	Above	1	73	26	Dark gray-brown silty clay, Cl
B-3	S-2	20.0 - 22.0	In	50	41	9	Dark gray-brown silty sand, SM
B-3	S-3	24.0 - 26.0	Contact	5	76	19	Dark gray silt trace sand, ML
Stratigraphic Averages:			Above	3.67	70.33	26.00	
			In	42.67	45.67	11.67	
			Base	35	58	7	
			Contact	6.00	60.33	33.67	
			Below	1	22	77	

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1973	Shell	North of Rand	Benzene		Shell Files
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3/10/78	Clark	Rand between Delmar and Olive	Gasoline		1978 Police Report
4/27/78	Clark	30' E. of Delmar on Elm	Gasoline	River line failed pressure test on 4/29	1978 Police Report
10/17/78	Clark	Elm	Gasoline	River line	1990 IEPA Report
1/8/81	ARCO		5 BBL gasoline		1990 IEPA Report
7/12/81	ARCO		24 BBL gasoline		1990 IEPA Report
6/7/82	ARCO		9 BBL fuel oil		1990 IEPA Report
11/10/82	Clark	N. Olive at E. Forest	Diesel Oil		1981 - 1990 Police Records
12/31/82	Clark	N. Olive at E. Forest			
4/16/83	Clark	Date at Olive		Overfilled tanks in empty lot at corner of Oak and Olive	1981 - 1990 Police Records
11/24/84	Clark	100 Bk. E. Elm	Light cycle oil	Oil seeping from ground	1990 IEPA Report
9/26/87	Clark	N. Olive at E. Cherry		Overfilled RW-L tank	1981 - 1990 Police Records
12/16/89	Shell	NE of Rand and Olive	294,000 gallons of unleaded		1990 IEPA Report

Table 2
Dates and Addresses of Hydrocarbon-Related Fires

Date	Address	Resident
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March 13, 1973	119 W. Date Street	Mr. Don Tinnon
April 28, 1975	119 E. Watkins	Mr. Robert Mays
March 24, 1978	119 W. Birch St.	Mrs. Rinda Rambo
March 27, 1978	117 W. Birch St.	Mr. Hugh Morse
March 30, 1978	105 W. Cherry St.	Mr. Kenneth Whalen
March 25, 1978	118 E. Date St.	Mr. Gene Overton
March 29, 1978	118 E. Date St.	Mr. Gene Overton
April 1979	4 fires at unknown locations	
July 21, 1981	102 E. Cherry St.	Mr. Harold Settles
June 11, 1985	501 N. Olive St.	Mr. Noah Greer
March 21, 1990	102 E. Cherry (2)	Mr. Harold Settles
May 16, 1990	117 E. Forest St.	Mr. Doug Neal
May 16, 1990	119 W. Birch St.	Ms. Laurie Carnes
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SHELL WELLS – TANNERY PROPERTY													
P-76	433.88		34.67	399.21			399.21	407.03	402.14	395.75	390.90	387.75	EPA-MAIN
P-77	435.17		35.95	399.22			399.22	406.00	403.57	399.05	387.20	384.05	MAIN
P-78	433.88		34.50	399.38			399.38	–	–	396.70	387.44	383.00	MAIN
P-79	433.26		33.72	399.54			399.54	–	–	396.38	390.65	387.00	MAIN
P-80	433.64		33.93	399.71			399.71	–	–	402.43	392.13	389.29	MAIN
P-81	433.80	32.42	34.21	399.59	401.38	1.79	401.02	–	–	402.23	391.93	389.09	EPA
P-104	433.28		17.54	415.74			415.74	–	–				UNNAMED
P-105	433.13	31.39	32.95	400.18	401.74	1.56	401.43	–	–	399.33	391.33		EPA
P-106	433.24		33.47	399.77			399.77	–	–	399.33	391.93	387.64	MAIN
P-107	432.46		27.70	404.76			404.76	–	–	396.73	390.16		EPA
EPA-7**	431.39		30.33	401.06			401.06	–	–	394.70	391.20	385.20	EPA-MAIN
SHELL WELLS AND CPTs – RAND AVENUE													
SP-1	429.63		8.76	420.87			420.87	*	*				RAND
SP-2(D)**	429.84		NM	NM			NM	*	*	*	*		RAND-EPA
SP-2B(D)	429.69		NM	NM			NM	409.69	405.45	402.51	388.82		EPA
SP-3	432.26		10.33	421.93			421.93	*	*				RAND
SP-4	430.91		9.22	421.69			421.69	*	*				RAND
SP-5	431.46		9.68	421.78			421.78	*	*				RAND
SP-6	433.63		12.66	420.97			420.97	*	*				RAND
SP-7	429.48		8.67	420.81			420.81	*	*				RAND
SP-8	429.53		8.69	420.84			420.84	*	*				RAND
SP-9	433.15		12.78	420.37			420.37	407.01	405.99	400.98			RAND
SP-10	433.19		12.28	420.91			420.91	414.50	407.21				RAND
SP-11	433.00		11.52	421.48			421.48	*	406.10				RAND
SP-12 (D)	432.92		28.34	404.58			404.58	407.01	405.99	400.98	*	*	EPA-MAIN
SP-13 (D)	433.27		30.32	402.95			402.95	*	406.10	*	*	*	EPA-MAIN
SP-14 (D)	429.33		27.73	401.60			401.60	*	*	*	*	*	EPA-MAIN
SP-15	428.96	10.22	10.27	418.69	418.74	0.05	418.73	409.49	405.63				RAND
SP-16	428.77		8.81	419.96			419.96	*	*				RAND
SP-17	428.68		10.51	418.17			418.17	404.16	401.94	399.26			RAND
SP-18 (D)	429.01		27.74	401.27			401.27	–	–	395.86	*	*	EPA-MAIN
SP-19	431.61		17.49	414.12			414.12	407.61	405.39				RAND
SP-20	431.88		15.92	415.96			415.96	409.41	406.52				RAND
SP-21	432.42		16.58	415.84			415.84	410.60	404.41				RAND
SP-22	430.91		12.41	418.50			418.50	*	*				RAND
SP-23	431.27		12.82	418.45			418.45	*	*				RAND
SP-24	429.46		8.60	420.86			420.86	*	*				RAND
SP-25	429.00	8.48	8.85	420.15	420.52	0.37	420.45	*	*				RAND
SP-26	428.99	8.36	8.55	420.44	420.63	0.19	420.59	*	*				RAND
CPT-1	430.50			NM			NM	409.99	405.07				
CPT-2	430.28			NM			NM	408.75	404.03				
CPT-3	431.88			NM			NM	406.45	400.71				
CPT-4	429.08			NM			NM	403.62	402.65				
CPT-5	428.68			NM			NM	406.53	404.89	396.69	388.49	384.39	
CPT-6	431.58			NM			NM	407.79	406.97				

TABLE 3
MONITOR WELLS OF THE HARTFORD VICINITY
3rd QUARTER 1990 GAUGING DATA AND AQUIFER ELEVATIONS

WELL ID	TOP OF WELL MSL ft	DEPTH TO PRODUCT ft	DEPTH TO WATER (Static)* ft	UNCORR. WT ELEV ft	PRODUCT ELEV. ft	PRODUCT THICKNESS ft	WT ELEV CORRECTED FOR PRODUCT ft	TOP OF RAND SAND ft	BASE OF RAND SAND ft	TOP OF EPA SAND ft	BASE OF EPA SAND ft	TOP OF MAIN SAND ft	SCREENED AQUIFER
CPT-7	429.98			NM			NM	407.83	403.73				
CPT-8	429.38			NM			NM	409.69	404.77				
CPT-9	430.08			NM			NM	409.57	401.37				
CPT-10	429.88			NM			NM	410.19	406.09				
CPT-11	430.50			NM			NM	412.46	404.25	398.51			
CPT-12	430.58			NM			NM	410.07	404.33				
CPT-13	432.18			NM			NM	407.57	405.11	401.83			
CPT-14	431.48			NM			NM	406.87	405.23	397.85			
CPT-15	430.28			NM			NM	408.95	405.67	399.11			
CPT-16	428.98			NM			NM	407.65	406.01				
CPT-17	431.38			NM			NM	404.31	403.49				
CPT-18	430.08			NM			NM	409.57	405.47				
CPT-19	431.78			NM			NM	406.35	405.53	399.79			
CPT-20	430.28			NM			NM	407.31	401.57				
CPT-21B	432.05			NM			NM	408.26	402.52	399.24	388.58	383.67	
CPT-22	431.68			NM			NM	411.99	402.97				
CPT-23	431.78			NM			NM	410.45	404.71				
AMOCO WELLS													
H-40	435.14		36.70	398.44			398.44	–	–	UNK.	UNK.	UNK.	MAIN
WELLS – VILLAGE OF HARTFORD													
B-3	431.27		27.05	404.22			404.22	–	–	–	–	404.58	MAIN
B-4	430.00			NM			NM	–	–	–	–	410.42	MAIN
B-7	432.98		30.33	402.65			402.65	–	–	–	–	411.72	MAIN
B-8	432.31	29.84	31.50	400.81	402.47	1.66	402.14	–	–	–	–	UNK.	MAIN
B-10	432.00			NM			NM	–	–	–	–	409.66	MAIN
B-14	432.00			NM			NM	–	–	–	–	400.11	MAIN
B-16	432.09	30.22	33.70	398.39	401.87	3.48	401.17	–	–	–	–	399.89	MAIN
B-17	430.00			NM			NM	–	–	398.70	391.55	387.69	MAIN
B-19	430.98		14.60	416.38			416.38	405.50	402.65	395.00	391.00	387.60	EPA-MAIN
B-24	432.21			432.21			432.21	–	–	–	–	400.97	MAIN
B-27	426.51		22.68	403.83			403.83	–	–	–	–	408.11	MAIN
B-29	429.00			NM			NM	–	–	–	–	403.35	MAIN
B-30	431.75	30.30	32.15	399.60	401.45	1.85	401.08	–	–	–	–	UNK.	MAIN
B-31	432.78	31.75	31.85	400.93	401.03	0.10	401.01	–	–	–	–	UNK.	MAIN
B-32	430.75	28.75	34.55	396.20	402.00	5.80	400.84	–	–	397.35	396.10	395.17	EPA-MAIN
B-33	430.86		28.65	402.21			402.21	–	–	–	–	UNK.	EPA-MAIN
B-34	432.63	30.85	31.75	400.88	401.78	0.90	401.60	–	–	–	–	UNK.	MAIN
B-35	430.88			NM			NM	–	–	–	–	399.08	MAIN
B-36	431.18	30.08	30.40	400.78	401.10	0.32	401.04	–	–	–	–	403.15	MAIN
B-37	432.41	30.93	32.20	400.21	401.48	1.27	401.23	–	–	–	–	UNK.	MAIN
B-38	430.60		28.55	402.05			402.05	–	–	–	–	UNK.	MAIN
B-39	433.00			NM			NM	–	–	–	–	387.39	MAIN
SHELL-1	431.18			NM			NM	–	–	–	–	403.15	MAIN
SHELL-2	432.62	30.50	34.10	398.52	402.12	3.60	401.40	–	–	–	–	UNK.	MAIN
RW-1	434.44		32.05	402.39			402.39	–	–	–	–	UNK.	MAIN
RW-2	432.86		31.95	400.71			400.71	–	–	–	–	387.39	MAIN

TABLE 3
MONITOR WELLS OF THE HARTFORD VICINITY
3rd QUARTER 1990 GAUGING DATA AND AQUIFER ELEVATIONS

WELL ID	TOP OF WELL MSL ft	DEPTH TO PRODUCT ft	DEPTH TO WATER (Static)* ft	UNCORR. WT ELEV ft	PRODUCT ELEV. ft	PRODUCT THICKNESS ft	WT ELEV CORRECTED FOR PRODUCT ft	TOP OF RAND SAND ft	BASE OF RAND SAND ft	TOP OF EPA SAND ft	BASE OF EPA SAND ft	TOP OF MAIN SAND ft	SCREENED AQUIFER
IEPA WELLS – VILLAGE OF HARTFORD													
EPA-1	430.50			NM			NM	–	–	395.50	394.00	388.69	EPA
EPA-2	429.60			NM			NM	–	–	–	–	410.10	MAIN
EPA-4	430.00			NM			NM	–	–	–	–	403.91	MAIN
EPA-5	429.40			NM			NM	–	–	–	–		MAIN
EPA-6	430.80			NM			NM	–	–	–	–	415.00	MAIN
EPA-7**	LOCATED AND LISTED AS A SHELL TANNERY PROPERTY WELL							–	–	394.70	391.20	385.20	EPA-MAIN
EPA-8	429.66			NM			NM	–	–	400.66			EPA
EPA-9	430.10			NM			NM	–	–	–	–	410.10	MAIN
EPA-10	429.20			NM			NM	–	–	–	–	401.26	MAIN
CLARK REFINERY WELLS													
B-3	431.56		30.35	401.21			401.21	–	–	UNK.	UNK.	UNK.	MAIN
B-6	432.69	31.53	34.59	398.10	401.16	3.06	400.55	–	–	UNK.	UNK.	UNK.	MAIN
B-27	430.91		26.99	403.92			403.92	–	–	UNK.	UNK.	UNK.	MAIN
B-21	431.46	30.61	30.71	400.75	400.85	0.10	400.83	–	–	UNK.	UNK.	UNK.	MAIN

	ELEVATION WAS ESTIMATED FROM BORING LOG OR CROSS-SECTION
	SAND UNIT WAS NOT PENETRATED. ELEVATION UNKNOWN.
–	SAND UNIT IS NOT PRESENT AT THIS WELL LOCATION
*	SAND UNIT SURFACE FELL BETWEEN SAMPLES. CPT DATA USED FOR DELINEATING RAND SAND
**	WELL SP-2 AND EPA-7 PLUGGED AND ABANDONED 10/21/91
NM	WELL WAS NOT GAUGED
UNK.	ELEVATION UNKNOWN. BORING LOGS NOT AVAILABLE.

Table 4
Site Monitoring Data

Well No.	Depth to Fluid (ft)	Depth to Water (ft)	Product Thickness (ft)
SP-1	-	15.85	-
SP-3	-	16.36	-
SP-7	15.13	16.69	1.56
SP-16	-	15.48	-
SP-8	-	16.36	-
SP-15	15.16	16.55	1.39
SP-17	-	16.04	-
SP-4	-	16.85	-
SP-5	-	17.33	-

Table 5
Site Monitoring Data

Well No.	Depth to Fluid	Depth to Water	Product Thickness
SP-3	-	7.51	-
SP-7	-	6.64	-
SP-16	-	7.61	-
SP-8	-	6.53	-
SP-15	7.49	8.09	0.60
SP-17	-	8.50	-
SP-4	-	6.14	-
SP-5	-	5.56	-
SP-14	-	27.05	-
SP-24	-	-	-
SP-25	6.19	7.61	1.42
SP-26	6.04	6.06	0.02

Table 6
Summary of Geotechnical Test Results
Rand Avenue Spill Site
October 22, 1991

Boring Number	Sample Number	Sample Depth (Feet)	Natural Moisture Content (Percent)	Dry Unit Weight (pcf)	Specific Gravity	Porosity (Percent)	Vertical Hydraulic Conductivity (cm/sec)
B-1	S-1	17.5 - 18.0	30.8	83.5	2.63	49.1	NT
B-1	S-2	19.0 - 21.0	34.1	NT	2.67	NT	NT
B-1	S-3	23.0 - 25.0	36.9	NT	2.66	NT	NT
B-1	S-4-1	25.5 - 26.0	34.2	85.5	2.60	47.3	NT
B-1	S-4-2	26.0 - 26.5	52.4	65.3	NT	NT	2.9×10^{-8}
B-1	S-4-3	26.5 - 27.0	48.8	71.7	2.69	57.3	NT
B-2	S-1	18.0 - 20.0	29.1	NT	2.69	NT	NT
B-2	S-2	20.0 - 22.0	39.0	NT	2.66	NT	NT
B-2	S-3-1	22.5 - 23.0	34.3	82.0	NT	NT	2.0×10^{-5}
B-2	S-3-2	23.0 - 24.0	36.6	81.4	2.74	52.4	NT
B-3	S-1	18.5 - 19.0	33.6	72.3	2.63	55.9	NT
B-3	S-2	20.0 - 22.0	32.9	NT	2.65	NT	NT
B-3	S-3	24.0 - 26.0	31.6	NT	2.67	NT	NT

pcf Pounds per cubic foot.

NT Not tested.

Table 7
Summary of Grain-size Distribution Analysis
Rand Avenue Spill Site
October 22, 1991

Boring Number	Sample Number	Sample Depth (Feet)	Relationship to Rand Sand	% Sand	Composition % Silt	% Clay	Description
B-1	S-1	17.5 - 18.0	Above	6	71	23	Dark gray-brown silty clay, trace sand, CL
B-1	S-2	19.0 - 21.0	In	70	21	9	Dark gray-brown silty sand, SM
B-1	S-3	23.0 - 25.0	Base	35	58	7	Dark gray-brown sandy silt, SM
B-1	S-4-1	25.5 - 26.0	Contact	13	60	27	Dark gray-brown silty clay, trace sand, CL
B-1	S-4-3	26.5 - 27.0	Below	1	2	77	Dark gray-brown clay with silt, CH
B-2	S-1	18.0 - 20.0	Above	4	67	29	Gray-brown silty clay, trace sand, CL
B-2	S-2	20.0 - 22.0	In	8	75	17	Dark gray-brown silt, trace sand, ML
B-2	S-3-2	23.0 - 24.0	Contact	0	45	55	Dark gray-brown clay with silt, CH
B-3	S-1	18.5 - 19.0	Above	1	73	26	Dark gray-brown silty clay, Cl
B-3	S-2	20.0 - 22.0	In	50	41	9	Dark gray-brown silty sand, SM
B-3	S-3	24.0 - 26.0	Contact	5	76	19	Dark gray silt trace sand, ML
Stratigraphic Averages:			Above	3.67	70.33	26.00	
			In	42.67	45.67	11.67	
			Base	35	58	7	
			Contact	6.00	60.33	33.67	
			Below	1	22	77	

Figure 34

Geraghty and Miller Regional Groundwater Map-Deep Aquifer

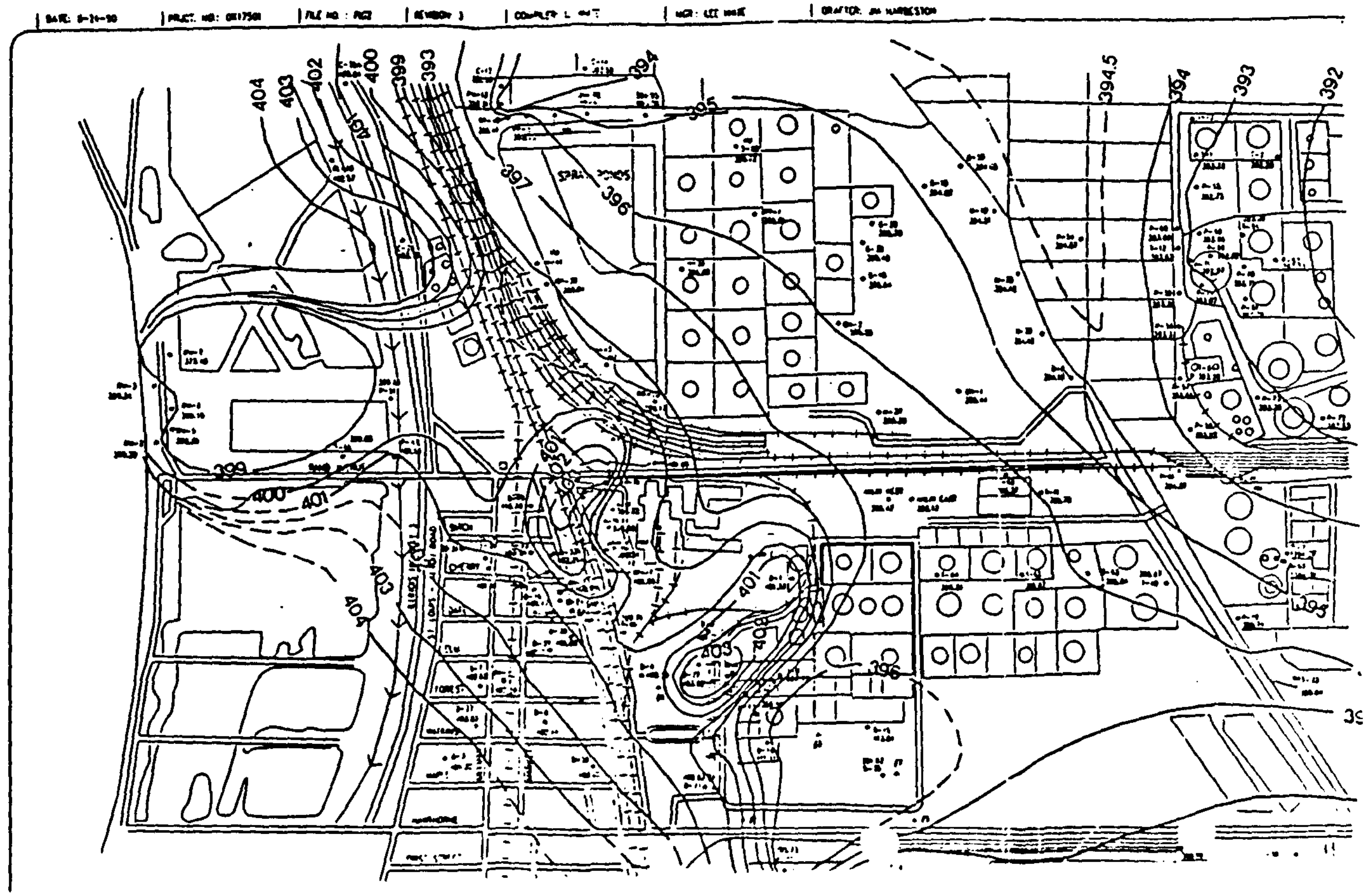

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FIGURE 35

Geraghty and Miller Regional Groundwater Map-Shallow Aquifer

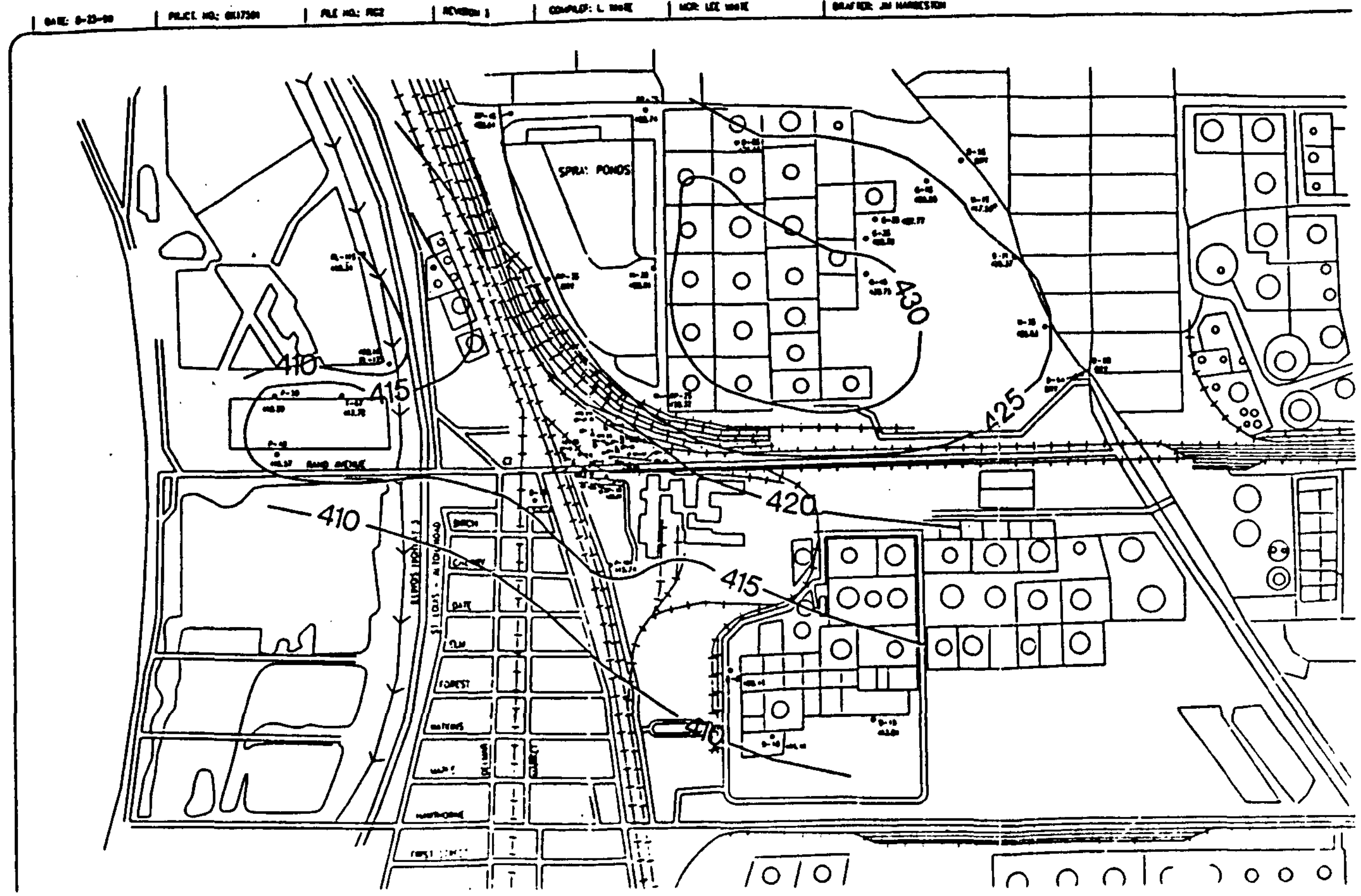
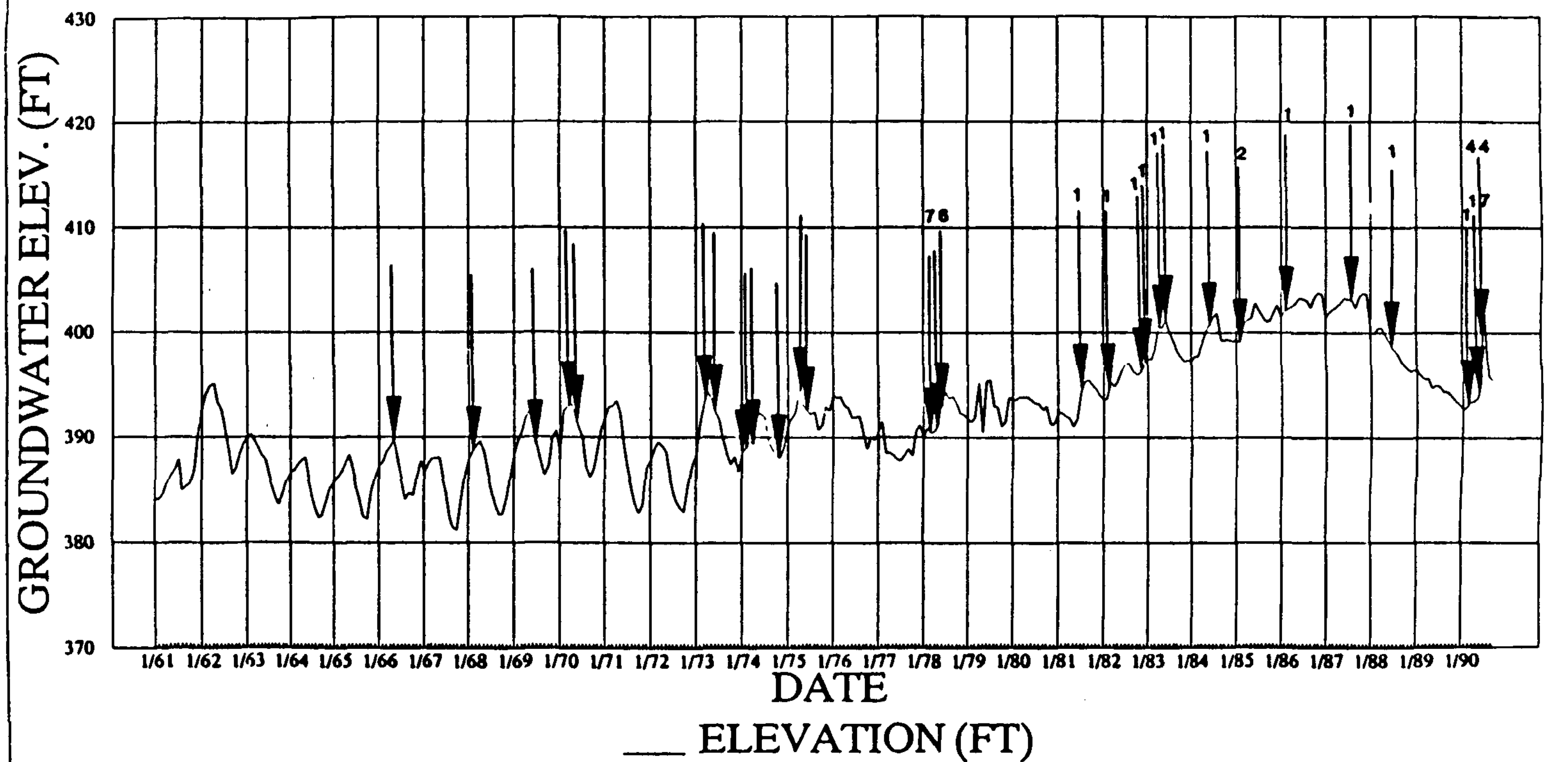


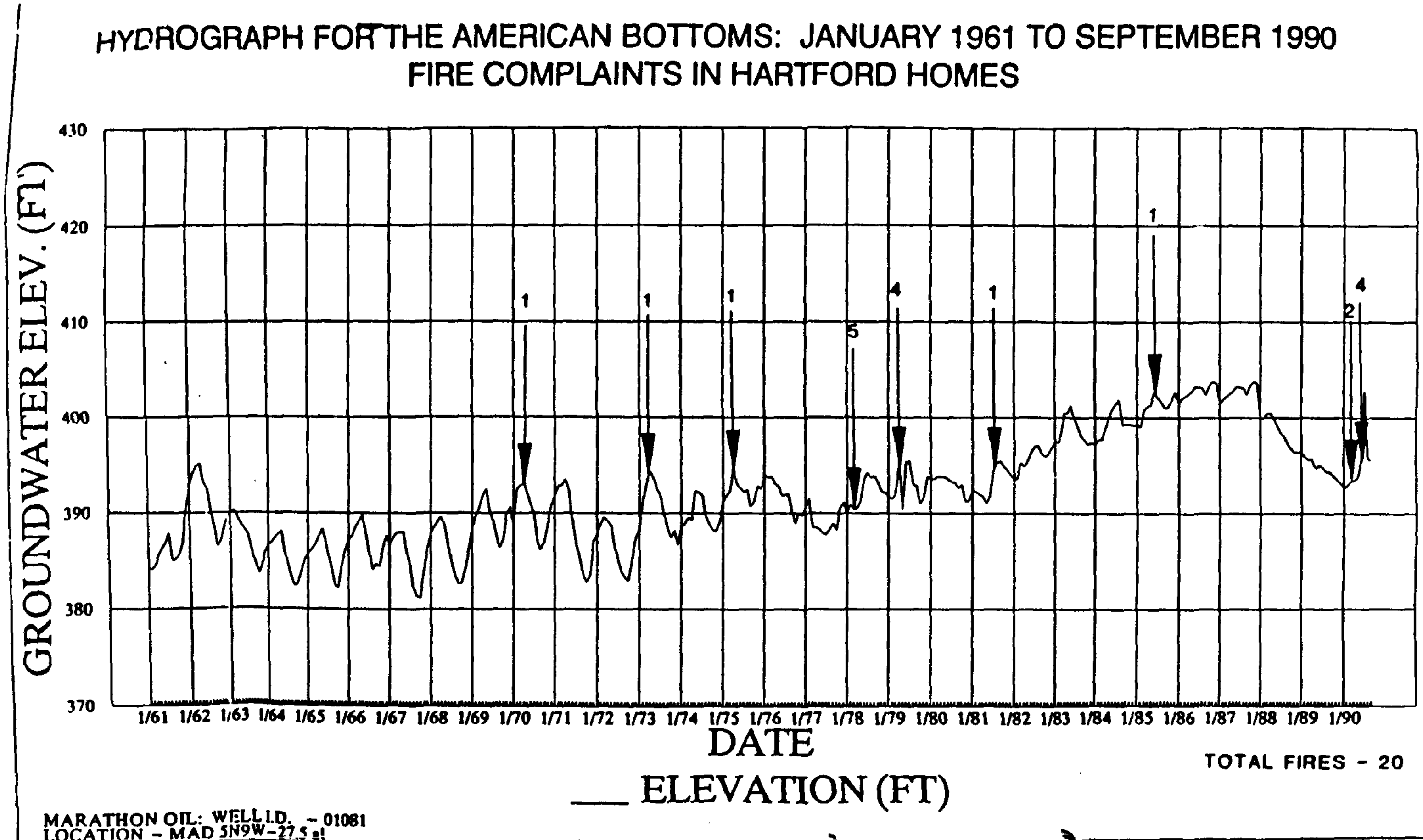
Figure 40

HYDROGRAPH FOR THE AMERICAN BOTTOMS: JANUARY 1961 TO SEPTEMBER 1990
HYDROCARBON ODOR COMPLAINTS IN HARTFORD HOMES



MARATHON OIL: WELL I.D. - 01081
LOCATION - MAD 5N9W-27.5 al

Figure 41



HYDROGRAPH FOR THE AMERICAN BOTTOMS: JANUARY 1961 TO SEPTEMBER 1990
FIRE COMPLAINTS IN HARTFORD HOMES
GROUNDWATER ELEV. (FT)
430
420
410
400
390
380
370
1/61 1/62 1/63 1/64 1/65 1/66 1/67 1/68 1/69 1/70 1/71 1/72 1/73 1/74 1/75 1/76 1/77 1/78 1/79 1/80 1/81 1/82 1/83 1/84 1/85 1/86 1/87 1/88 1/89 1/90
DATE
1
1
1
5
4
1
1
2
4
TOTAL FIRES - 20
ELEVATION (FT)
MARATHON OIL: WELL I.D. - 01081
LOCATION - MAD 5N9W-27.5 el

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FIGURE 35

Geraghty and Miller Regional Groundwater Map-Shallow Aquifer

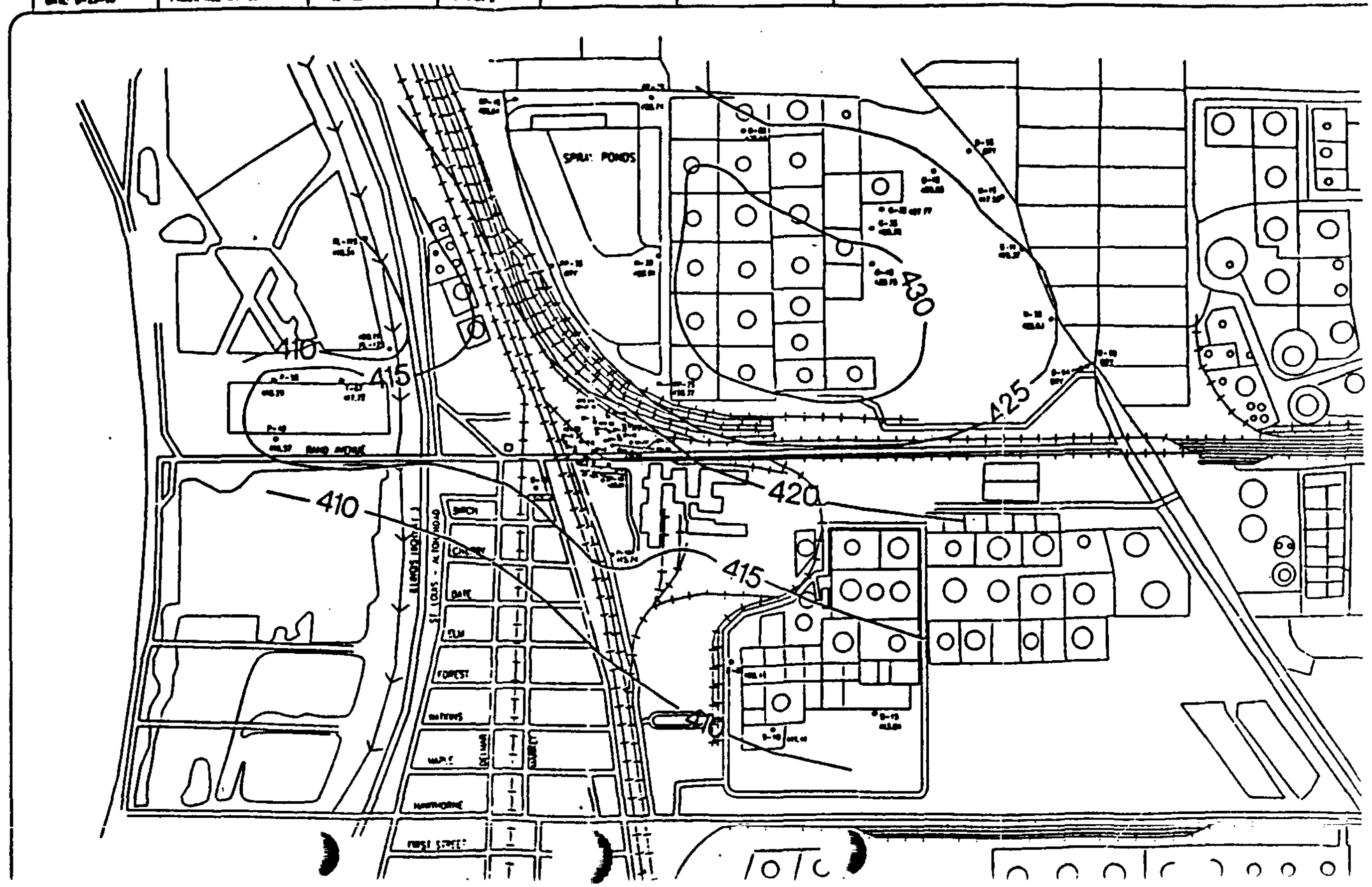
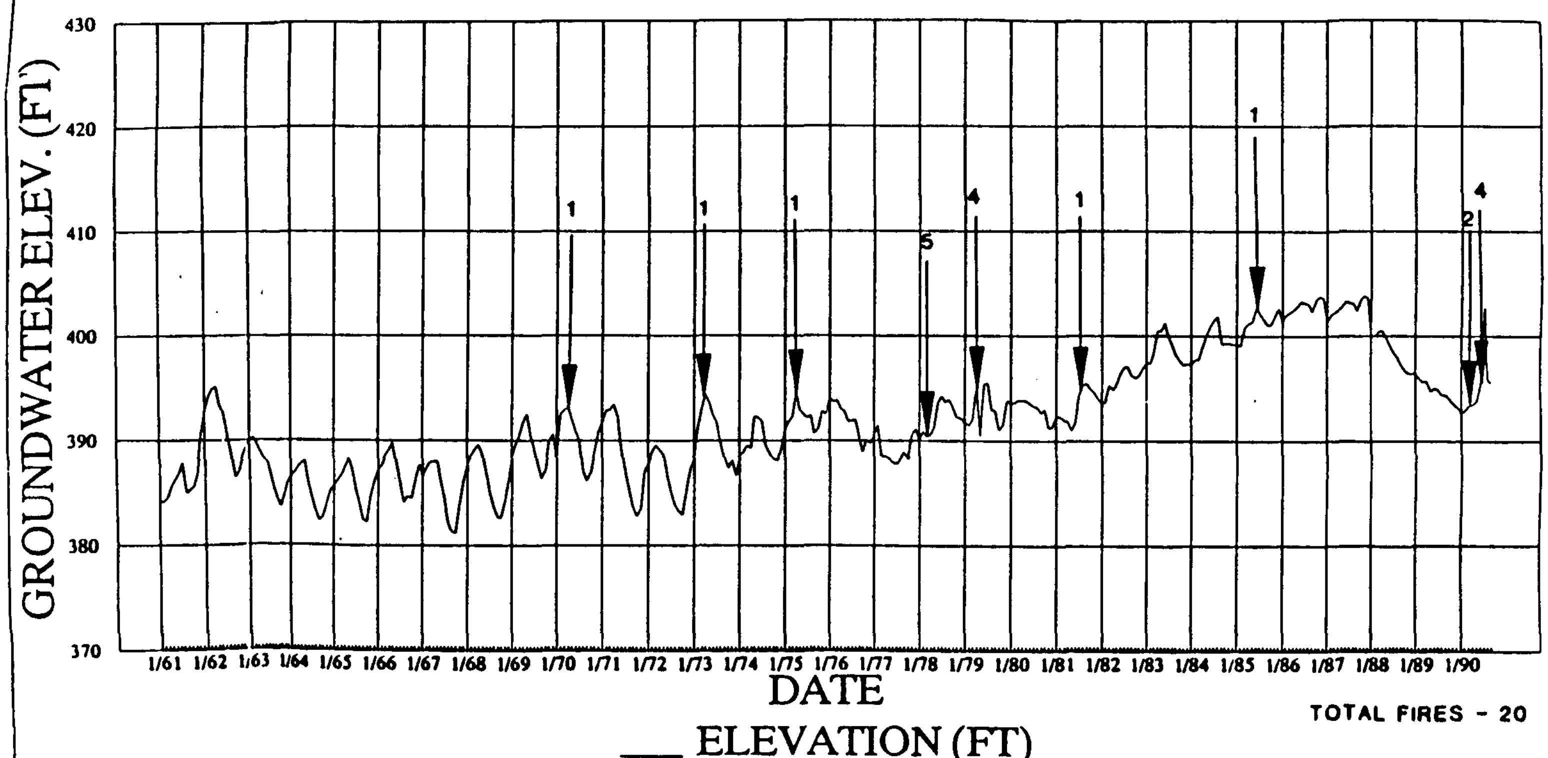


Figure 41

HYDROGRAPH FOR THE AMERICAN BOTTOMS: JANUARY 1961 TO SEPTEMBER 1990
FIRE COMPLAINTS IN HARTFORD HOMES



MARATHON OIL: WELL I.D. - 01081
LOCATION - MAD 5N9W-27.5 al